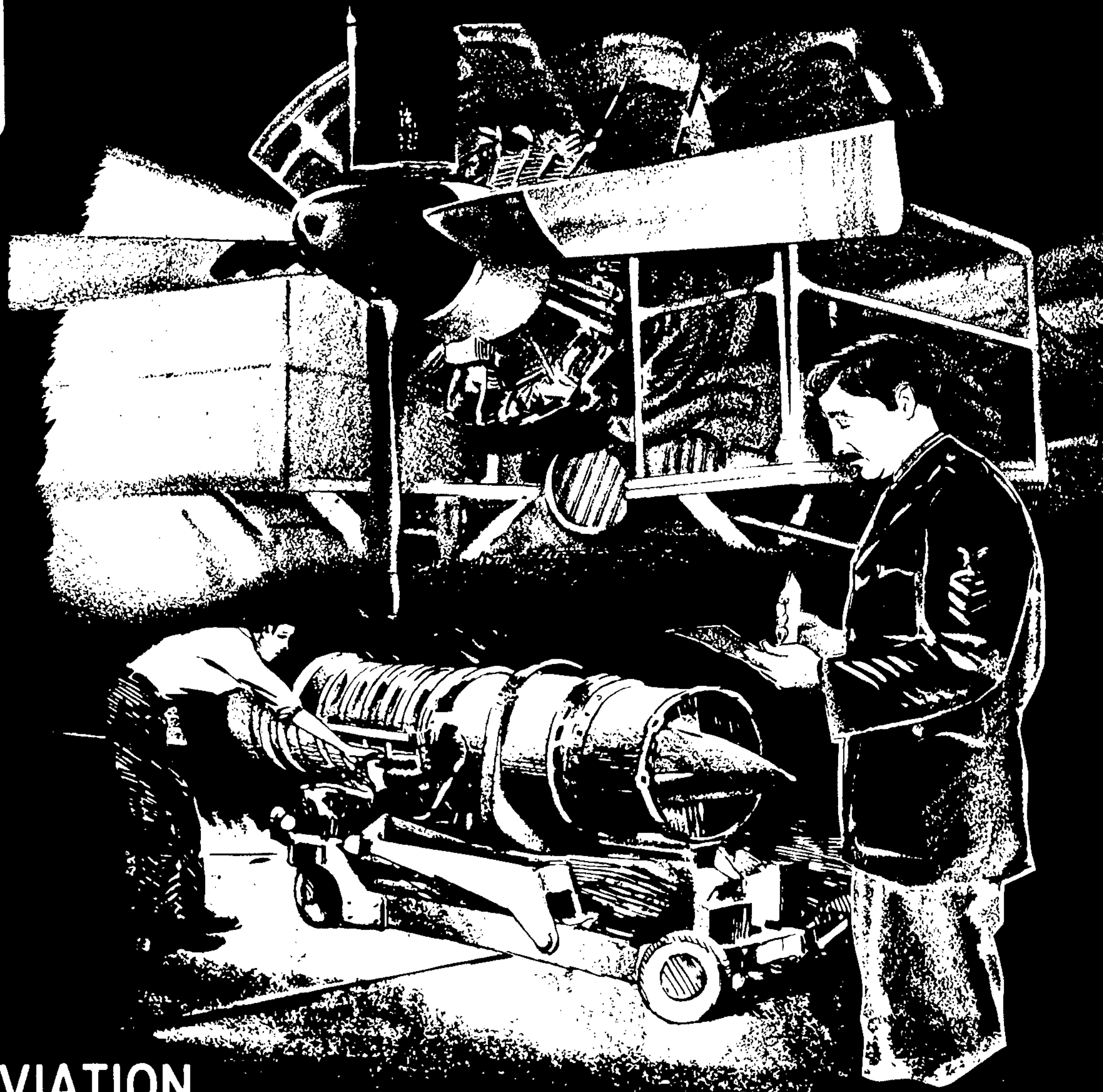

AVIATION MACHINIST'S MATE 1 & C

NAVAL EDUCATION AND TRAINING COMMAND
RATE TRAINING MANUAL AND NONRESIDENT CAREER COURSE

NAVEDTRA 10324-A

Although the words "he," "him," and "his" are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading *Aviation Machinist's Mate 1 & C,* NAVEDTRA 10324-A.

Naval Education And Training Program Development Center

AVIATION MACHINIST'S MATE 1 & C

NAVEDTRA 10324-A

DEPARTMENT OF THE NAVY ★ CHIEF OF NAVAL EDUC AND TNG ★

1984 Edition Prepared by
ADC Clifford L. Newton and
ADCS James E. Thomas

PREFACE

This Rate Training Manual and Nonresident Career Course (RTM/NRCC) form a self-study package that will enable ambitious Aviation Machinist's Mates to help themselves fulfill the requirements of their rating.

Designed for individual study and not formal classroom instruction, the RTM provides subject matter that relates directly to the occupational standards for the AD1 and ADC. The NRCC provides the usual method for satisfying the requirements for completing the RTM. The set of assignments in the NRCC includes learning objectives and supporting items designed to lead students through the RTM. The occupational standards used as minimum guidelines in the preparation of this manual are to be found in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068-D

This Rate Training Manual was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training. Technical review of the manuscript was provided by personnel in the AD school, NATTC, NAS Memphis, Millington, Tennessee; the Naval Aviation Logistics Center, Patuxent River, Maryland; and the Naval Air Systems Command Headquarters, Washington, D.C.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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3. Power Plant Repair 3-1
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Nonresident Career Course follows Index

CHAPTER 1

FUEL SYSTEM MAINTENANCE

Fuel system maintenance is primarily the responsibility of the AD rating. To properly supervise the maintenance on a fuel system, you, a senior AD, must be familiar with the different types of fuel systems used in naval aviation.

The purpose of a fuel system is to deliver a uniform flow of clean fuel, under constant pressure, to the engine's fuel control. This supply of fuel must be adequate to meet all of the engine's demands at various altitudes and attitudes of flight. Because of the particular needs of the various types of aircraft, fuel tanks vary in size, shape, construction, and location. Fuel tanks can be an integral part of an aircraft wing, but most often fuel tanks are separate units, and as such may be placed in different configurations. In this chapter, the F/A-18 fuel system is used as the representative example.

AIRCRAFT FUEL SYSTEM DESCRIPTION

The fuel and in-flight refueling systems provide continuous fuel flow to the aircraft's engines. The fuel is carried in four interconnected fuselage tanks and two internal wing tanks. External fuel is carried by three 315-gallon elliptical tanks or 330-gallon cylindrical tanks. All of the aircraft's tanks can be refueled on the ground through a single pressure refueling point. Airborne refueling is accomplished through the use of the retractable, electrohydraulic in-flight refueling probe. Float-type fuel level control valves control the fuel level during refueling of all the fuel tanks. The internal wing tanks, tank 1 and tank 4, are the transfer tanks. These tanks are arranged so that internal fuel gravity transfers even if the fuel transfer pumps fail. The same fuel level control valves used in refueling are used to control fuel levels during transfer and to control the fuel levels in tank 1 and tank 4 during internal wing transfer. Regulated engine bleed air pressure is used to provide the pressure necessary for fuel transfer from the external tanks, and it maintains a positive pressure on all of the internal fuel tanks.

Fuel level sensors are used to control the fuel level in tanks 2 and 3 (the engine feed tanks) during fuel transfer from tanks 1 and 4. All internal and external fuel (except the engine feed tanks) may be dumped overboard through a flame arrester outlet located in each vertical fin of the aircraft. The internal fuel tanks are vented through outlets located in the vertical fins. The external fuel tanks are vented overboard through pressure relief valves in the individual tanks. The fuel quantity indicating system provides fuel quantity indications in pounds.

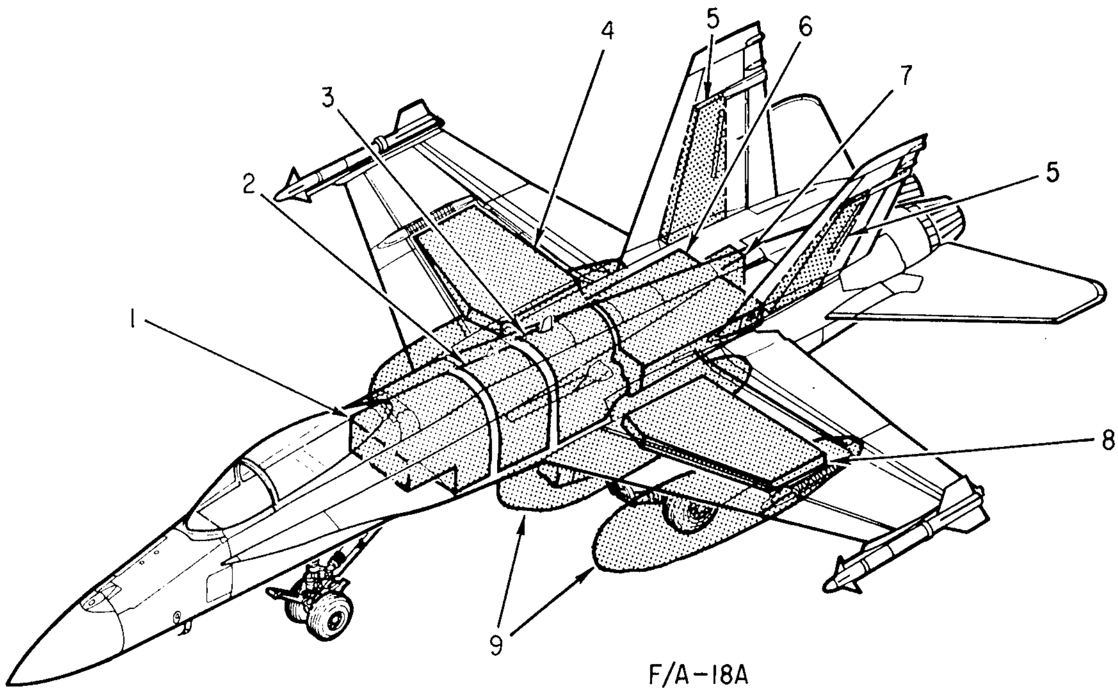
The internal fuel tanks are located forward of the engines for safety reasons. The internal wing tanks contain foam for fire/explosion protection. The lower section of the feed tanks are self-sealing to protect the system and to provide for enough fuel to "get home." Figure 1-1 shows the general fuel tank arrangement in the aircraft.

AIRCRAFT FUEL TANKS

The aircraft fuel storage system is made up of four fuselage tanks, two wing tanks, and three external tanks. The following paragraphs give a description of each of the fuel storage tanks.

Fuselage Fuel Tanks

All of the fuselage fuel tanks are of a bladder-type construction. Bladder-type fuel cells are discussed later in this chapter. These tanks are supported in the tank cavity by various brackets, fittings, and nylon lacing cords. Fuel gravity flows between the fuselage fuel tanks through four



1. No. 1 fuel tank
2. No. 2 fuel tank
3. No. 3 fuel tank
4. Right wing tank
5. Vertical stabilizer vent tank
6. No. 4 fuel tank
7. Vent tank
8. Left wing tank
9. Aircraft external fuel tank

204.102

Figure 1-1.—F/A-18 aircraft fuel storage tank location.

interconnect valves located at the bottom of each tank.

Feed Tanks

The internal transfer system is designed to keep fuel in the feed tanks (tanks 2 and 3) at all engine power settings. Fuel from tanks 1 and 4 flows to the feed tanks, where the level is maintained by the fuel level sensors. The feed tanks are internally divided by horizontal inverted flight baffles. Each baffle assembly has check valves that are normally open to allow fuel flow from the top to the bottom of the fuel tank. During a negative "G" or inverted flight, the flappers of the check valves swing closed, thus retaining the fuel in the area of the transfer jet ejector. The lower areas of tanks 2 and 3 are self-sealing. If an area of the self-sealing tank is damaged, the slick inner layer of natural gum rubber activates in the fuel and forms a seal, providing the aircraft with a "get home" fuel reserve. Self-sealing fuel tank construction is covered later in this chapter. Figure 1-2 shows a fuselage tank, and figure 1-3 shows a feed tank.

Wing Tanks

The wing tanks are an integral part of the wing structure. They transfer fuel to fuel tanks 1 and 4. These wing tanks are sealed with a channel sealant injected from outside of the wing.

Fuel Tank Cavity Vent and Drain

The space between each bladder-type tank and its cavity is vented and drained through tubes that extend outside the lower fuselage. During a rapid climb, air in the cavity expands and is vented overboard. During a rapid descent, air inflow pressurizes the voids in the tank cavity. This venting process prevents stretching of the fuel tank.

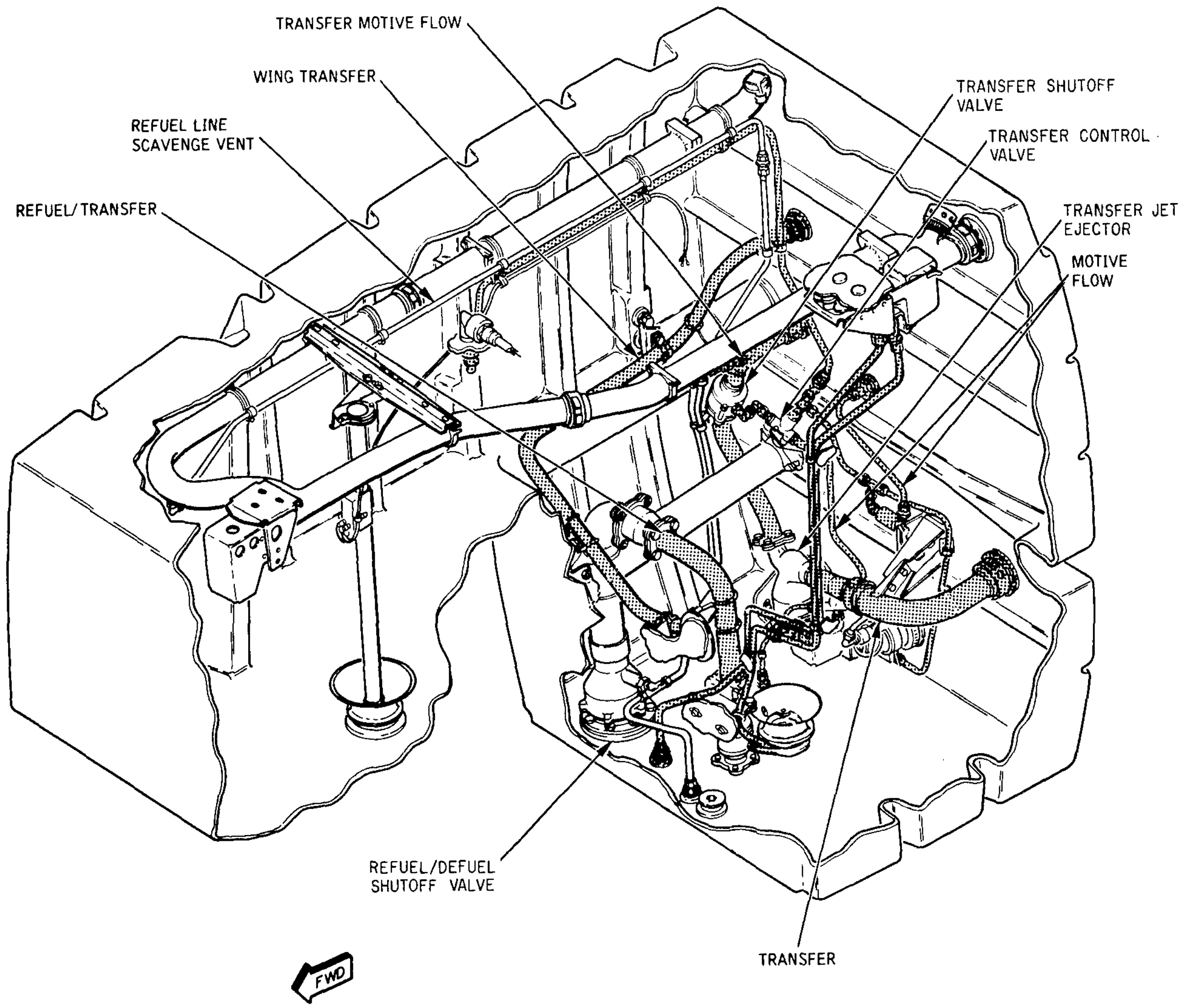


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Figure 1-2.—Cutaway view of No. 1 fuselage fuel storage tank.

ENGINE FUEL SYSTEM DESCRIPTION

The engine fuel supply system is made up of a separate fuel feed system for each engine. Each engine is supplied pressurized fuel by two motive flow/boost pumps. Each of the fuel feed tanks contains an engine fuel boost ejector that provides positive fuel pressure to the inlet of the motive flow/boost pump. Each of the boost pumps accepts fuel from a separate engine fuel system. The number 2 tank feeds the left engine and the number 3 tank feeds the right engine.

The engine fuel feed lines are interconnected by a cross-feed valve and cross-feed lines located downstream of the motive flow/boost pumps. This arrangement allows operation of both of the aircraft's engines from either feed tank with pressurized fuel. Located in each fuel feed tank is an inverted flight fuel compartment that provides approximately 10 seconds of inverted flight.

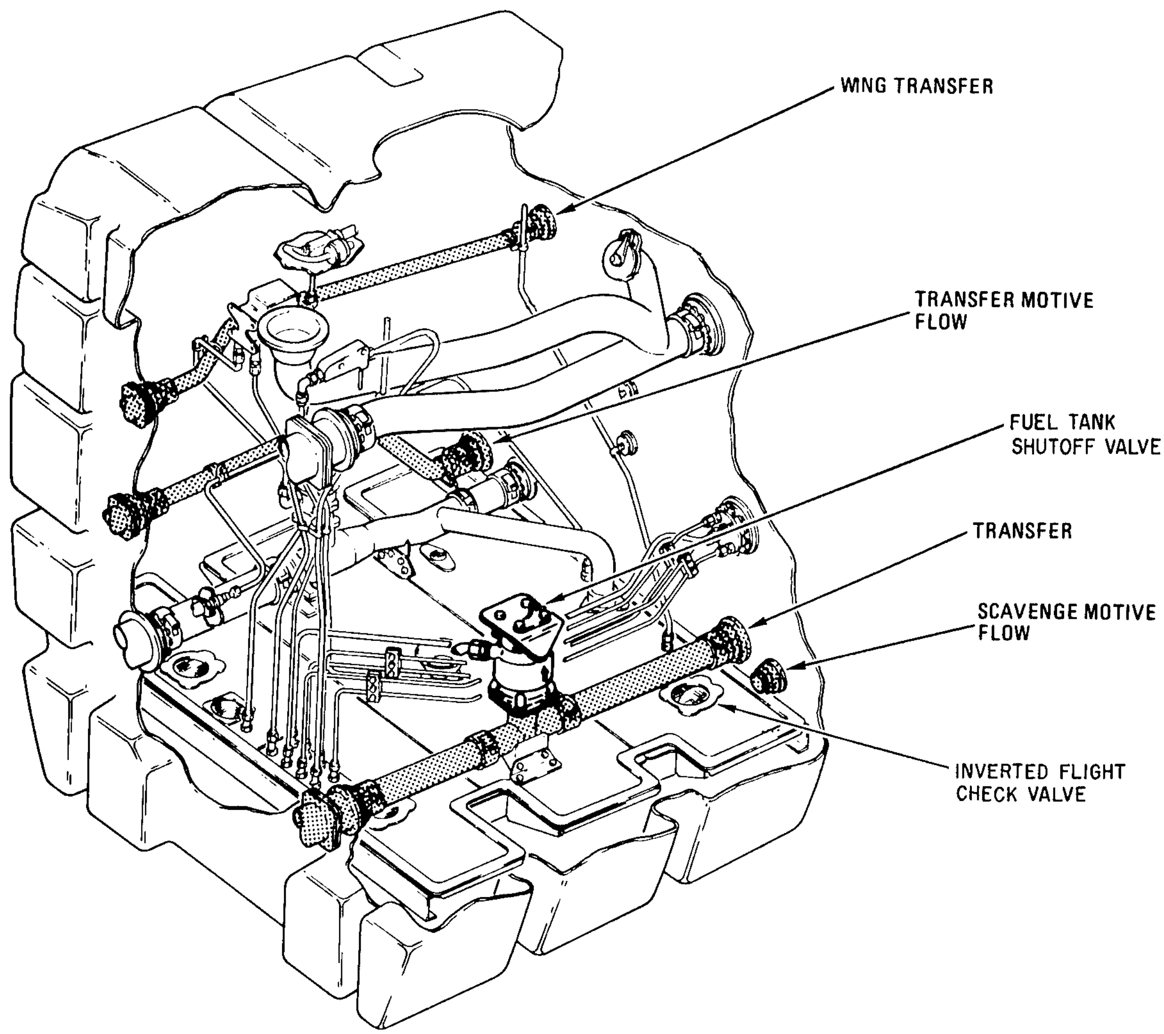

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Figure 1-3.—Cutaway view of No. 2 fuel feed tank.

Engine Fuel Boost Ejectors

The engine fuel boost ejectors supply a positive fuel pressure to the motive flow/boost pumps. They are mounted in the inverted flight compartments of each fuel feed tank. Each ejector has dual inlets and a shuttle valve to provide an inlet that is submerged in fuel at any aircraft attitude.

Engine Fuel Turbine Boost Pump

The turbine boost pump consists of a turbine wheel shaft, two mixed flow impellers, nozzle housing, pump housing and two impeller screens. The impellers are mounted at opposite ends of the turbine wheel shaft. The nozzle housing assembly is positioned in the pump housing between the upper and lower impellers and turbine wheel. The impeller screens are secured over the two impellers to prevent foreign objects from entering the turbine boost pump.

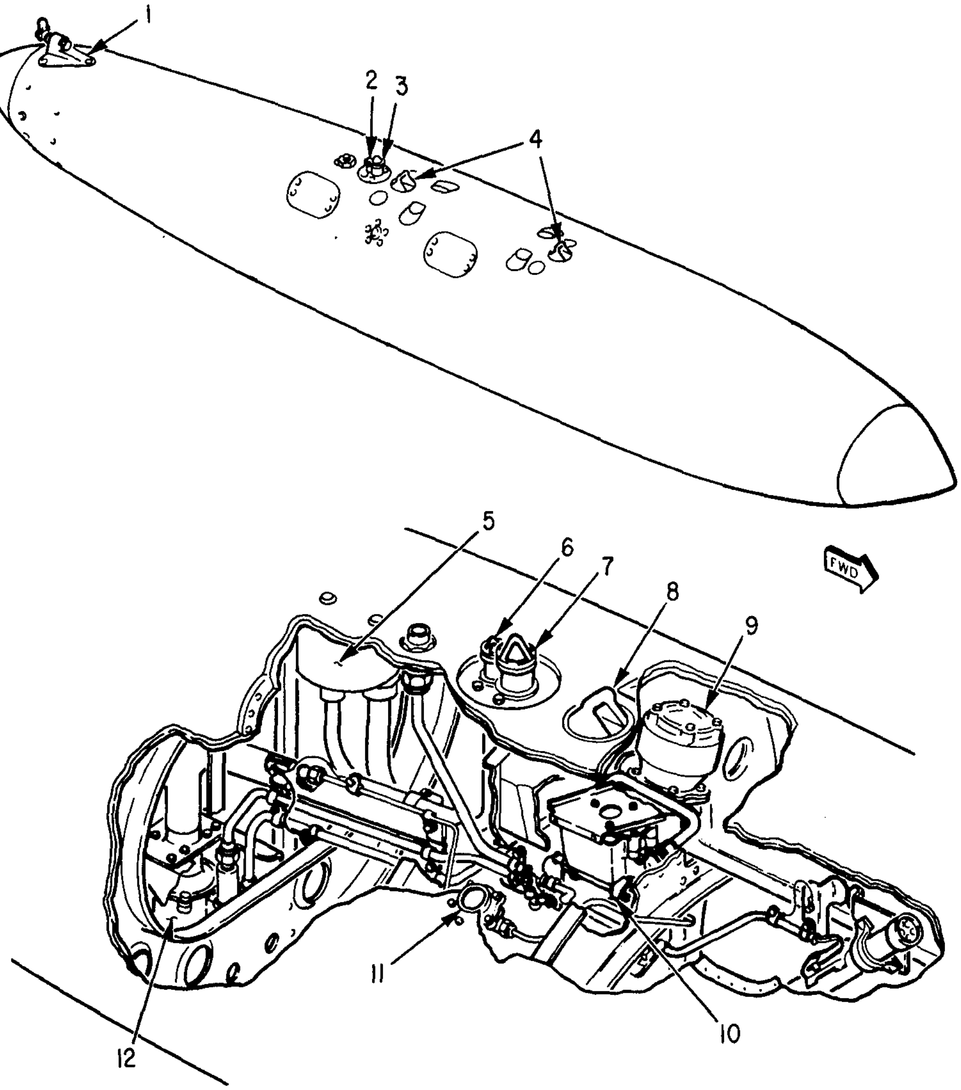
EXTERNAL FUEL SYSTEM DESCRIPTION

The three external fuel tanks are mounted at the inboard wing and center line pylons of the aircraft. They provide added fuel that can be

transferred to any of the internal fuel tanks that will accept it.

Elliptical Fuel Tank

The elliptical external fuel tank has a fuel capacity of 315 gallons. This tank can be manually or electrically prechecked during refueling. The tank can be refueled through the aircraft's refueling system. The system incorporates valves that operate automatically without electrical power for transfer, refueling, precheck, and pressurization. Fuel transfer from this type of tank can be electrically stopped during flight. (See figure 1-4.)



1. **Jettison pivot**
2. **Pylon air probe**
3. **Pylon fuel probe**
4. **Suspension lugs**
5. **Pressurization and vent valve**
6. **Pylon air probe**
7. **Pylon fuel probe**
8. **Suspension lug**
9. **Pressure relief valve**
10. **Air pressure regulator check valve**
11. **Manual precheck valve**
12. **Refuel/transfer shutoff valve**

204.105

Figure 1-4.—Elliptical external fuel tank (with cutaway view).

Cylindrical Fuel Tank

The cylindrical external fuel tank functions and uses the same type of valves as the elliptical fuel tank. The cylindrical fuel tank can be alternately refueled through a fuel filler cap or through the aircraft's refueling system. The tank's capacity is 330 gallons of fuel. (See figures 1-4 and 1-5.)

External Fuel Transfer

External fuel tank pressurization and transfer is accomplished through the use of regulated engine bleed air. An external tank pressure regulator maintains 15 to 18 psi air pressure to each of the external tanks. Once the tank is pressurized, fuel then transfers through the refuel/transfer shutoff valve into the refueling manifold. External fuel is then transferred to any of the fuel tanks that will accept the fuel. The refuel/transfer valve will close automatically when the external tank is empty.

The external tank air pressure regulator is energized closed when the aircraft has weight on the wheels or when the in-flight refueling probe is extended. This will prevent the tanks from being pressurized while the aircraft is on the ground, during an arrested landing, or during in-flight refueling.

External Fuel Tank Jettison

The external fuel tanks can be selectively jettisoned or all jettisoned at one time, such as during an emergency situation. The external tank to pylon fuel/air coupling valves will automatically close the fuel transfer and air pressurization tubes once the tanks are jettisoned.

MAINTENANCE STATUS DISPLAY AND RECORDING SYSTEM

The F/A-18 aircraft incorporates computers to aid in the maintenance of its systems. The fuel system is included in this computerization.

The maintenance status display and recording system (MSDRS) receives continuous inputs from the fuel system and sends the data received to the mission computer system for processing. If the mission computer systems detects a fuel system failure or malfunction, it sends the applicable maintenance code for the problem to the MSDRS digital display indicator located in the nosewheel well of the aircraft for storage and display. These codes are then read and transcribed to aid the mechanic in troubleshooting and correcting the fuel system discrepancy.

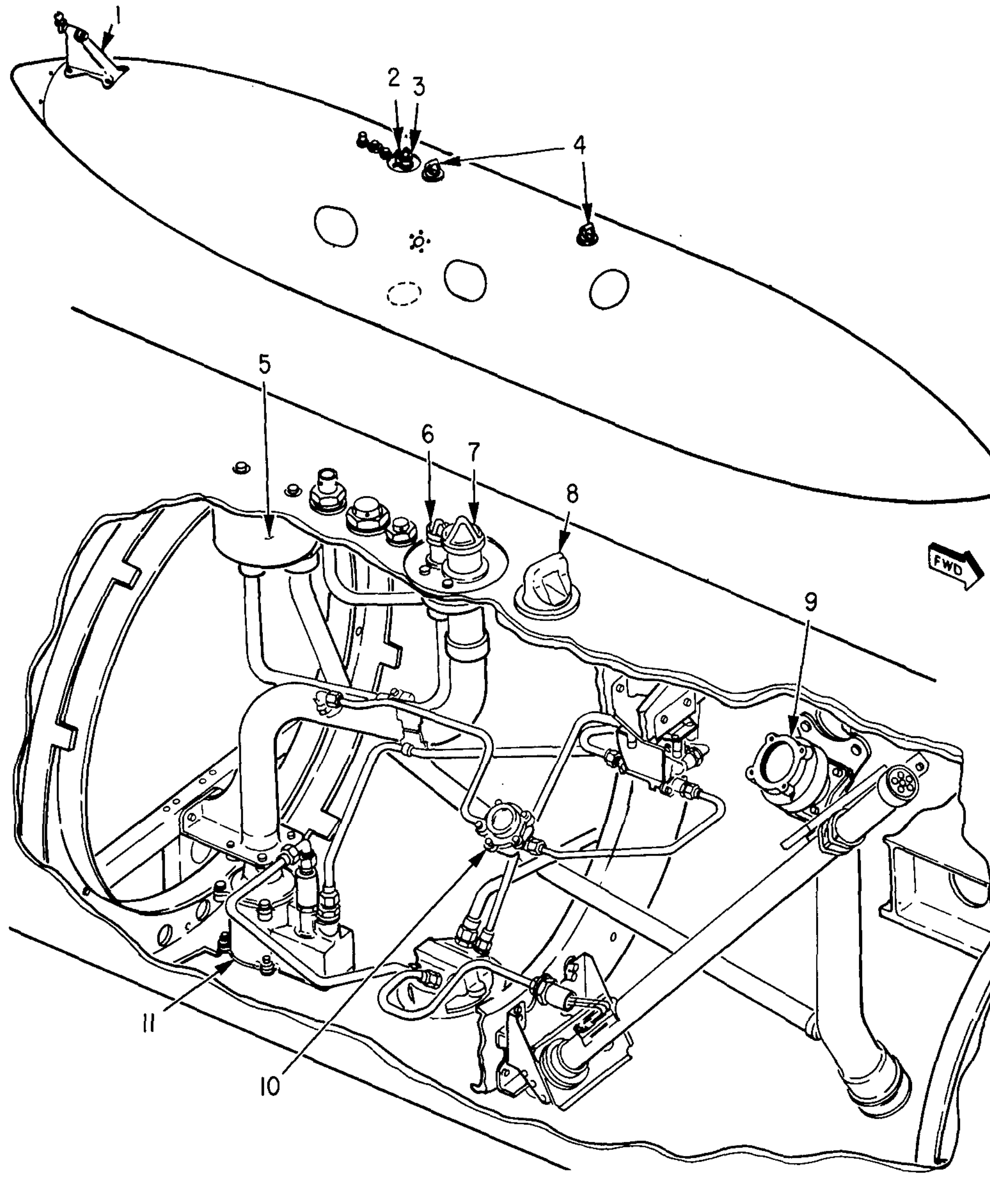
FUEL TANK CONSTRUCTION

The material selected for the construction of a particular fuel tank depends upon the type of aircraft in which the tank will be installed and the mission for which the aircraft is designed. Fuel tanks and the fuel system in general must be made of materials that will not react chemically with any fuels that may be used.

Fuel tanks must be provided with facilities for inspection and repair of the tank. This requirement is met by installing access panels in the fuselage and wings. Fuel tanks must be equipped with sumps and drains to collect sediment and water and to provide for fuel sampling. The construction of the tank must be such that any hazardous quantity of water in the tank will drain to the sump so that the water can be drained from the fuel tank. As a senior AD, you should be familiar with the different types of fuel tank construction. The types of fuel tank construction are discussed in the following paragraphs.

SELF-SEALING FUEL CELLS/ CONSTRUCTION STANDARD TYPE

A self-sealing cell is a fuel container that automatically seals small holes or damage caused during combat operations. A self-sealing cell is not bulletproof, but it is puncture sealing. As illustrated in



1. Jettison pivot
2. Pylon air probe
3. Pylon fuel probe
4. Suspension lugs
5. Pressurization and vent valve
6. Pylon air probe
7. Pylon fuel probe
8. Suspension lug
9. Pressure relief valve
10. Manual precheck valve
11. Refuel/transfer shutoff valve

204.106

Figure 1-5.—Cylindrical external fuel tank (with cutaway view).

figure 1-6, the bullet penetrates the outside wall of the cell and the sticky, elastic sealing material surrounds the bullet. As the bullet passes through the cell wall into the cell, the sealant springs together quickly and closes the hole. When the fuel in the tank comes in contact with the sealant, it makes the sealant swell, completing the seal. This sealing action reduces the fire hazard brought about by leaking fuel and helps to keep the aircraft's fuel system functional so the aircraft can continue to operate and return to its base.

The most commonly used type of self-sealing fuel cells is the construction standard type. The construction standard type is a semiflexible cell, made up of numerous plies of material. There are four primary layers of material used in the construction of the self-sealing cell—the inner liner, nylon barrier, sealant, and retainer. All self-sealing fuel cells now in service contain these four primary layers of materials. If additional plies are used in the construction of the cell, they must be related to one of the primary plies.

The inner liner material is the material used in the inside of the cell. It is constructed of solid synthetic rubber or nitrile coat nylon fabric (Buna N). Its purpose is to contain the fuel and prevent it from coming in contact with the sealant. This prevents premature swelling or deterioration of the sealant.

NOTE: Buna N is an artificial substitute for crude or natural rubber. It is not affected by petroleum fuels, making it ideal for use in fuel cells. However, Buna N is a slightly porous material, which makes it necessary to use a nylon barrier to prevent the fuel from contacting the sealant.

The nylon fuel barrier is an unbroken film of nylon. The purpose of the nylon fuel barrier is to prevent the fuel from diffusing further into the cell wall. During construction, the nylon is applied by brush, swab, or spray in three or four hot coats to the outer surface of the inner liner.

The sealant material is the next layer of material used in fuel cell construction. It remains dormant in the fuel cell until the cell is ruptured or penetrated by a projectile. When this occurs, it is the function of the sealant to seal the

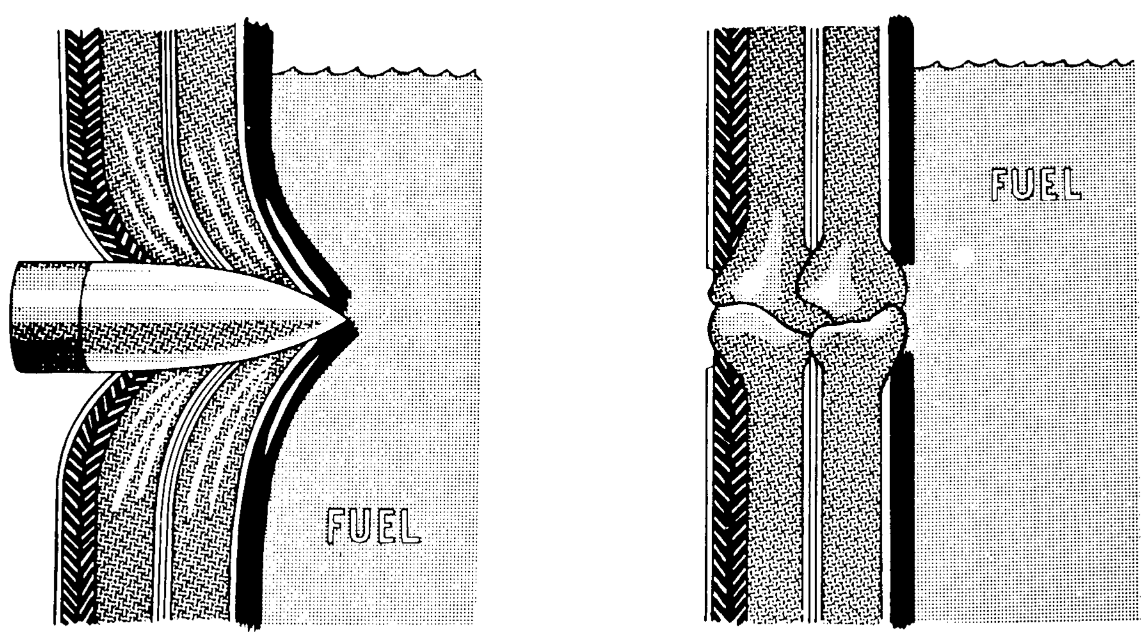


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Figure 1-6.—Bullet sealing action.

ruptured area so the fuel will not flow through to the exterior of the fuel cell. (See figure 1-6.)

This mechanical reaction results because rubber, natural or synthetic, will "give" under the shock of impact, thereby limiting damage to a small hole in the fuel cell. The fuel cell materials will allow the projectile to enter or leave the cell. The materials then return to their original position. This mechanical reaction is almost instantaneous.

The chemical reaction takes place as soon as fuel vapors penetrate the inner liner material and reach the sealant. The sealant, upon contact with fuel vapors, will extend or swell to several times its normal size. This action effectively closes the rupture and prevents the fuel from escaping. The sealant is made of natural gum rubber.

The retainer material is the next layer of material used in fuel cell construction. The purpose of the retainer is to provide strength and support, and to increase the efficiency of the mechanical action by returning the fuel cell to its original shape when punctured. The retainer is made of nylon cord fabric impregnated and coated with fuel-resistant synthetic rubber nitrile (Buna N).

One variation of the construction standard self-sealing fuel cell is shown in figure 1-7. The cell is constructed from the four primary materials. It consists of the inner liner, nylon fuel barrier, two sealant plies, and three retainer plies.

Baffles and internal bulkheads are used inside the cell to help retain the shape of the cell and prevent sloshing of the fuel. They are constructed of square woven fabric impregnated with Buna N. Flapper valves are fitted to some baffles to control the direction of fuel flow between compartments or interconnecting cells. The baffles are constructed of Micarta, Bakelite, or aluminum.

These plies of materials, baffles, internal bulkheads, and flapper valves, together with the necessary fittings, make up the typical construction standard self-sealing fuel cell.

BLADDER-TYPE FUEL CELLS

A nonself-sealing fuel cell, commonly called a bladder-type cell, is a fuel container which does not self-seal holes or punctures. The advantages of using a bladder-type fuel cell are the reduction in weight, the simplicity of repair techniques, and the reduced procurement costs as compared to self-sealing fuel cells.

To give minimum possible weight, bladder-type cells are usually made of a very thin material. They require 100 percent support from a smooth cavity. The cell is made slightly larger than the cavity of the aircraft so the weight or internal pressure of the fuel is borne by the airframe structure.

The thinner wall construction of the bladder-type cell provides increased fuel capacity (compared to the self-sealing type of fuel

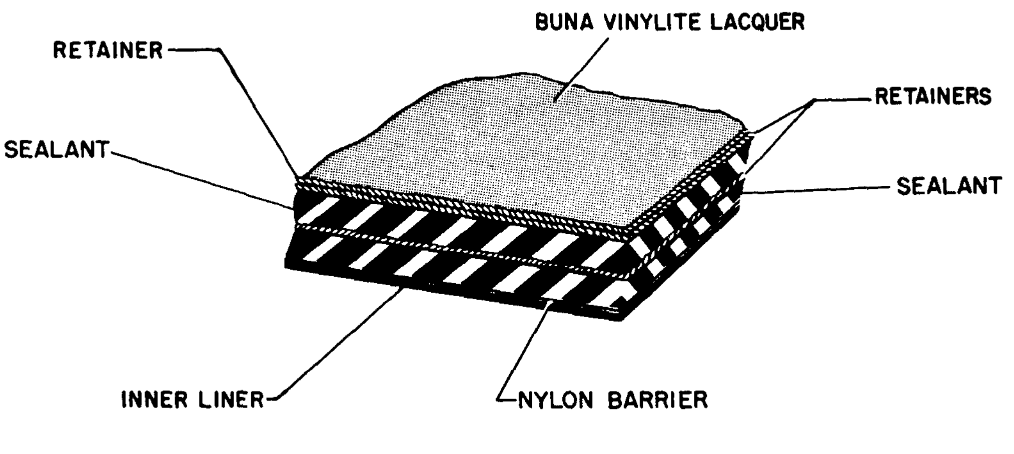

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Figure 1-7.—Self-sealing fuel cell (construction standard).

cell), thus increasing the range of the aircraft. There are two types of bladder fuel cells—rubber and nylon.

Rubber-Type Bladder Cells

The rubber-type bladder cells are fabricated in the same manner as self-sealing cells in that they have a liner, nylon barrier, and a retainer ply. The sealant layers are omitted. All three plies are placed on the building form as one material in the following order: liner, barrier, and retainer. Figure 1-8 illustrates this type of cell construction.

The inner liner may consist of Buna rubber, Buna N coated square-woven fabric, or Buna N coated cord fabric. The purpose of the inner liner is to contain the fuel and provide protection for the nylon barrier.

The nylon barrier consists of three to four coats of hot nylon applied by brush, swab, or spray. The purpose of the nylon barrier is to keep fuel from diffusing through the cell wall.

The retainer consists of Buna N coated square-woven fabric or cord fabric. The purpose of the retainer ply or plies is to lend strength to the fuel cell and provide protection for the nylon fuel barrier.

Nylon-Type Bladder Cell (Pliocel)

Nylon bladder cells differ in construction and material from the Buna N rubber cells. This type of cell may be identified by the trade name "Pliocel" stenciled on the outside of the cell. The Pliocel construction consists of two layers of nylon-woven fabric laminated with three layers of transparent nylon film.

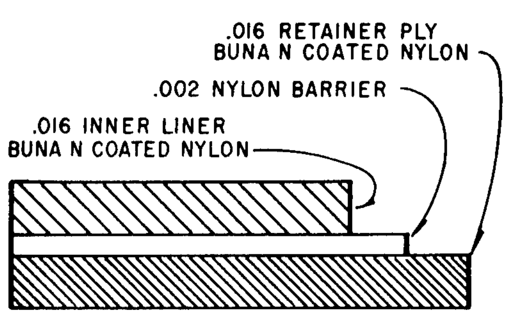

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Figure 1-8.—Bladder cell construction.

The repair of this type of cell must be accomplished by entirely different methods and with different materials. The adhesive and Buna N rubber used with the rubber bladder cells cannot be used with the nylon cell. For repair procedures and materials for all types of fuel cells, the *Aircraft Fuel Cells and Internal/External Tanks* manual, NA 01-1A-35, should be used.

MAINTENANCE

Before any maintenance is performed on a fuel tank/cell, a check of the applicable aircraft maintenance manual is required. If the aircraft maintenance manual is not specific enough to cover the type of maintenance that is required, refer to the *Aircraft Fuel Cell and Internal/External Tank* manual, NA 01-1A-35, for additional information. If you find conflicting information between the specific fuel system portion of the aircraft maintenance manual and the NA 01-1A-35, the procedures and materials required in the NA 01-1A-35 manual must take precedence for fuel tank/cell maintenance.

SAFETY PRECAUTIONS

The most important consideration in working with any fuel system maintenance task is the safety of personnel. Aircraft fuels are extremely hazardous because of the explosive and toxic dangers that are always present. The health hazards associated with aviation fuels (breathing of vapors, spillage on skin or in the eyes, or swallowing) must be avoided. It is not feasible to describe all the potential problems or dangers that may arise in the performance of any type of fuel system maintenance. As an AD, it is your responsibility to be thoroughly aware of all the safety practices and procedures that must be strictly followed.

Fuel vapors are very harmful when they are inhaled. It takes a very small percentage of these vapors to cause very serious effects on the personnel who are working in the area of these vapors. Fuel vapors are heavier than air and will collect in the lower areas of the fuel tank/cell. Unless these vapors are removed by the use of

forced-air ventilation, the fuel vapors can present a definite hazard for an indefinite period of time. Personnel should avoid the inhalation of these vapors and always be alert to recognize the first signs of the toxic effect of breathing these vapors. The symptoms of inhalation include nausea, dizziness, and headaches. If a person should experience these symptoms at anytime during the course of fuel system maintenance, immediately stop the maintenance operation and move the individual to a source of fresh air. If the individual appears to be completely overcome by the vapors, he/she needs prompt medical attention. When personnel are working with aviation-type gasolines and fuel is swallowed or the skin becomes saturated with gasoline, lead poisoning can occur. This is because of high content of the very poisonous tetraethyl lead. The principle danger of lead poisoning occurs when it becomes necessary for personnel to actually enter the fuel tank/cell in which leaded gasolines were used. When working with any type of aviation fuel, personnel should always avoid prolonged contact with the fuel. If a person's clothing becomes saturated, he/she should remove them as soon as possible and wash off the affected areas with soap and water. It is essential to know the location of approved eyewash stations and how they are used.

To make sure personnel are protected from the health hazards associated with aviation fuels, the use of required protective clothing and equipment should always be the first priority before starting any type of fuel system maintenance. Specific items such as respirators, coveralls, proper shoes, and safety goggles are usually available for use by personnel who are required to work with aviation fuels. Appendix B of NA 01-1A-35 contains specific information on all of the required safety equipment.

DEFUELING, DEPUDDLING, PURGING, AND INERTING

Prior to an inspection, entry of personnel, or repair of any fuel tank/cell, specific functions must be accomplished. These functions are discussed in the following paragraphs. A definition of each function is provided to allow you to become familiar with its terms.

1. Defueling. Defueling is the process of transferring fuel from the aircraft tank/cell into mobile, portable or fixed tanks.

2. Depuddling. Depuddling is the process of removing residual fuel from cells/tanks and low-point drains after defueling.

3. Purging. Purging is the process for removing inert vapors, fuel vapors, or any other vapor capable of producing a combustible or toxic atmosphere.

4. Inerting. Inerting is the process of obtaining an oxygen-deficient noncombustible atmosphere in a fuel cell/tank.

Before you perform any defueling, depuddling, purging, or inerting on an aircraft, it must be parked in an area specifically authorized for such operations. Figures 1-9 and 1-10 illustrate typical setups ashore and afloat. Some of the safety precautions that must be observed when selecting an appropriate site or using an existing one are as follows:

1. Do not apply external electrical power.

2. Disconnect battery.

3. The area must be roped off 50 feet in all directions from the aircraft.

4. The aircraft must be a minimum of 100 feet from any building or smoking area.

5. The area must be clearly marked from all approaches with warning placards. For example, "Danger—Open Fuel Tanks—Unauthorized Personnel Keep Out."

6. The area must have appropriate fire extinguishers as required by fire regulations.

7. High frequency radar equipment mounted in aircraft or in ground installations must not be operated within 100 feet of the area. The site location must be at least 300 feet from any ground radar installation.

8. Aircraft engines or support equipment gas turbine engines will not be operated within 100 feet of the area.

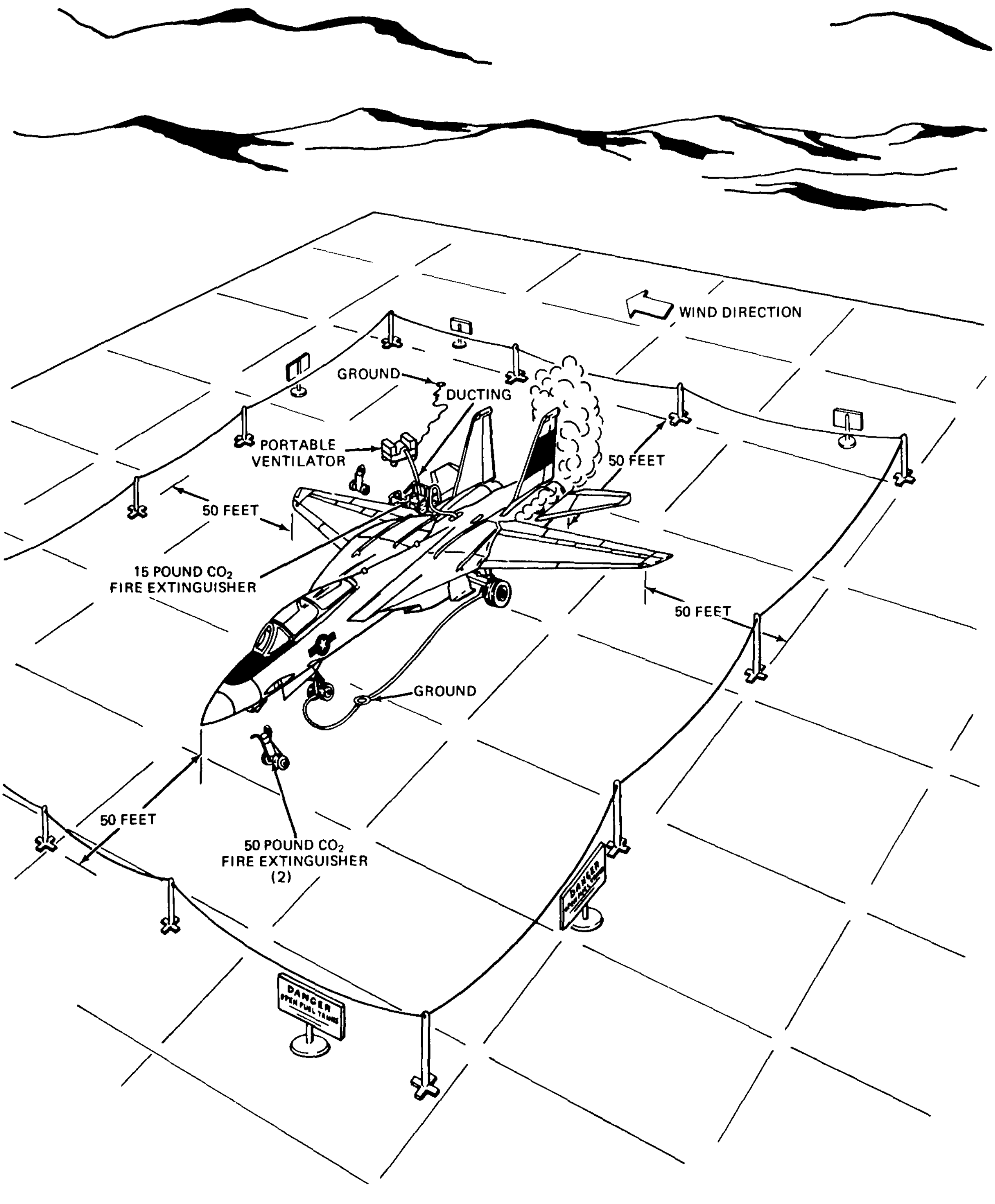

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Figure 1-9.—Purging station setup (shore station).

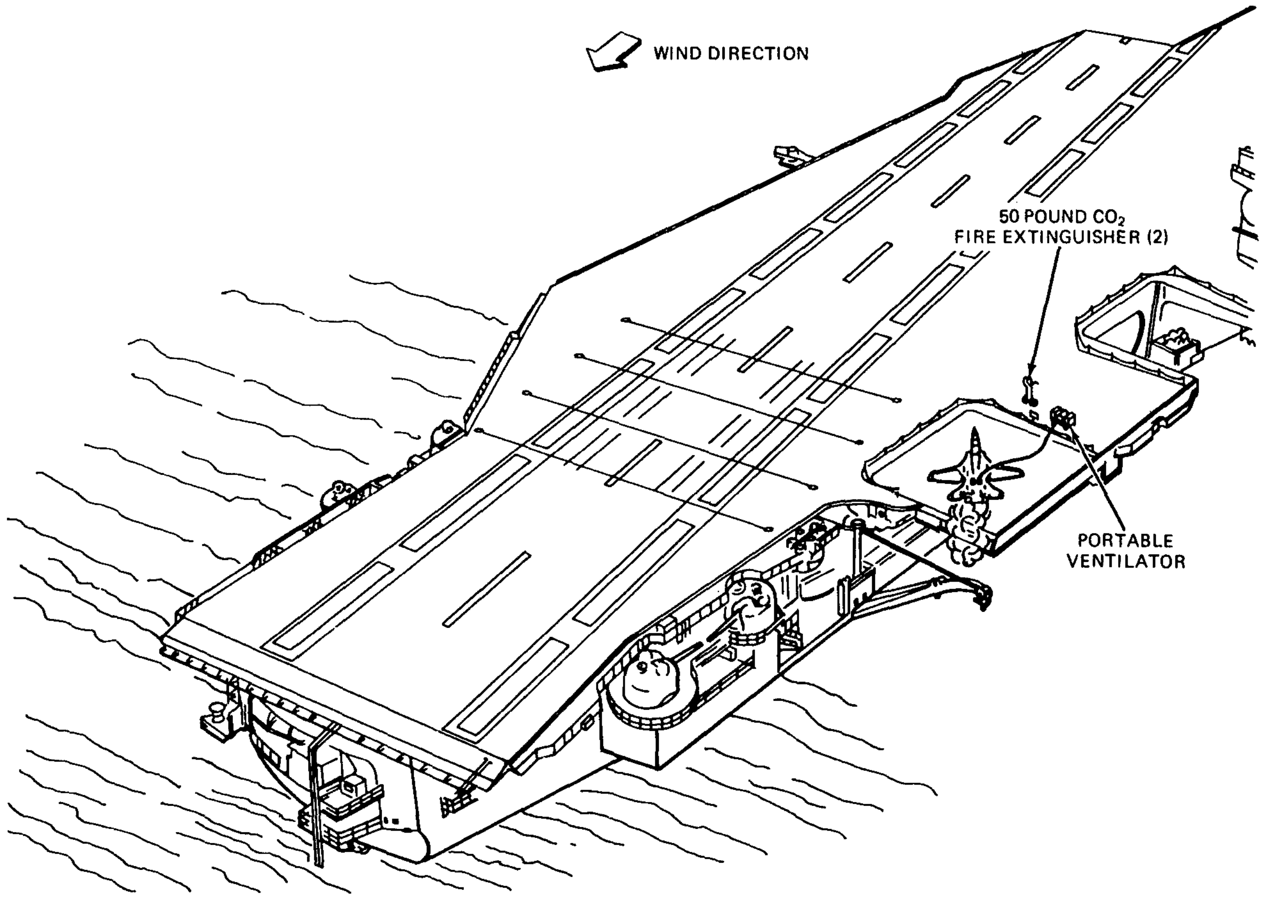

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Figure 1-10.—Purging station setup (shipboard).

Defueling of the aircraft should be performed in the following manner:

1. Fire extinguishers must be inspected for serviceability and manned at all times.

2. All maintenance personnel should remove all matches, lighters or other spark-producing devices prior to entering the designated defueling area.

3. Nonsparking chocks are required to chock the aircraft.

4. The defueler must be parked as far from the aircraft as possible. It should be parked heading away from the aircraft in case it becomes necessary to move the defueler in an emergency.

NOTE: All the required grounding and bonding cables must be attached before the aircraft or defueler tanks are opened.

5. You should always ground the aircraft to an approved grounding point. The aircraft must be grounded to the defueler. The grounding cable for the nozzle must be grounded to a metal part remote from the tank/cell. This minimizes static electricity between the nozzle and the aircraft. Then you attach the bonding cable from the nozzle to the aircraft.

6. Personnel requirements should consist of one person to man each fire extinguisher, one person to operate the defueler, one person to operate the aircraft defueling panel, and one

person to operate the fuel system control panel inside the aircraft, if applicable.

You must remember that no maintenance of any type will be allowed on the aircraft during defueling. Once the defueling operation is complete, all of the aircraft fuel tank/cell and low-point drains should be left open to drain into approved 5-gallon safety containers.

CAUTION: Some fuel cells contain fuel after the water drain valves have stopped dripping (approximately 2 gallons). When you remove the access cover, catch the fuel in a 5-gallon safety container.

Depuddling of the aircraft fuel tank/cell is always a hazardous operation because it requires the entry or partial entry of personnel into an aircraft tank/cell to remove any residual fuel that was not removed from the tank/cell during defueling. In an effort to minimize the hazards associated in depuddling, all maintenance personnel are required to work in pairs. One person should remain outside the tank/cell to act as a safety observer while the other actually enters the tank/cell to do the depuddling. The same general safety precautions that apply to the defueling operation apply to depuddling. The aircraft battery connector and aircraft power receptacle should always be tagged with an appropriate warning placard to indicate that power is NOT to be applied to the aircraft under any circumstances. Before you perform any depuddling, refer to the aircraft maintenance manual and NA 01-1A-35 for the proper support equipment that must be used.

When you purge a tank/cell, attach an approved air blower to the tank/cell and ensure that all personnel remain clear of the removed access panel. After allowing approximately 30 minutes for the blower to remove the toxic vapors, you should stop the air blower and have the tank/cell tested by a gas-free engineer to ensure the tank/cell is safe for personnel to initiate depuddling. If after this time a "safe" condition is not reached, reinstall the air blower for at least an additional 15 minutes and have the test repeated. Continue the venting and testing, if necessary, until the tank/cell can be certified safe for personnel. Once the air inside the tank/cell has been certified and documented as safe, the outside safety observer and the individual who is going to enter the tank/cell should obtain all the necessary protective clothing and equipment and proceed with the depuddling.

NOTE: The two individuals should always be connected by a safety line in case of an emergency.

The next step in depuddling is to remove all the necessary access panels and covers required. Then, immediately after entering the tank/cell, the individual must cap or seal all openings leading from other possible sources of fuel or fuel vapors. Depuddling can be accomplished by using an approved explosion-proof vacuum cleaner, or a cellulose sponge or cheesecloth can be used to remove the residual fuel from the tank/cell.

When you perform maintenance on a fuel tank/cell, the next step is purging. There are currently three approved methods you may use to purge the aircraft fuel tank/cell. They are the air blow, air exhaust, and the oil purge methods.

The air blow purging method uses an air blower and ducting to force fresh outside air into the tank/cell. The air exhaust purge method uses an air blower and ducting to draw fresh outside air through the tank/cell. The oil purge method utilizes lubricating oil, MIL-L-6081, grade 1010, to dilute the fuel vapors in the defueled tank/cell. The oil purge method is the most desirable of the three methods when it is known that it will be necessary to perform extensive repairs to the aircraft other than maintenance solely related to the fuel system. The oil purge method will normally keep the tank/cell safe for personnel for a period of approximately 10 to 15 days.

NOTE: In all methods of purging, it is mandatory that the tank/cell be certified by a gas-free engineer and documented as being "safe for personnel."

The final step required before conducting any maintenance on fuel tanks/cells is inerting. There are two approved methods of inerting—siphon and pressure. Siphon inerting is the process by which the air space of a pressurized fuel system or an individual tank/cell is slightly pressurized by injecting an inert gas (usually dry nitrogen)

through a fuel system pressurization valve while the system/tank/cell is being defueled. This method is suitable for inerting pressurized fuel systems in cases where it will not be necessary to open the tanks or cells to conduct inspections or work inside. The siphon method is considered the most efficient method for inerting a single tank or cell, as well as interconnected tanks or cells.

Pressure inerting is accomplished by pressurizing normally unpressurized fuel systems. The air space of the system or individual tank/cell is slightly pressurized by injecting an inert gas (dry nitrogen) through an adapter fitting placed in the tank/cell filter opening. Pressure inerting is used when it will not be necessary to open the tank/cell to conduct inspections or work inside the tank/cell and when defueling of the aircraft will not be required.

LEAK SOURCE ANALYSIS

In modern aircraft, the fuel systems are designed to operate satisfactorily under all conditions such as aircraft acceleration and deceleration, temperature and pressure changes, or any of the various flight attitudes. However, no matter how good the design, the fuel system will not function as designed if it is not maintained properly. A significant number of fuel leaks can be attributed to incorrect maintenance procedures used in installing fuel tanks/cells, components, lines, and fittings. By referring to the applicable aircraft maintenance manual and learning the general procedures discussed in this section, you will have little difficulty in locating the source of an aircraft fuel leak.

Leak source analysis is the process involving the use of the aircraft maintenance manual, fuel system schematic diagrams, installation diagrams, and trouble-shooting charts. The most common method of analysis is the methodical process of elimination to isolate the source of a fuel leak. In addition to the items already discussed, it may well serve you to first screen the aircraft discrepancy book (ADB) to possibly save many man-hours looking for a leak. The review of a prior fuel system discrepancy may reveal maintenance that resulted in spilled fuel that was not properly cleaned up or the improper installation of a fuel system component. Never assume that the first leak you find is the only leak in the system. Completely check and test the entire fuel system as directed by the applicable maintenance manual.

Severe leaks that spill large quantities of fuel into the tank/cell drain system, or just below or adjacent to the tank/cell, are usually caused by a rupture or cut fuel cell, loose interconnecting fittings, or cut or distorted O-rings. These leaks can usually be detected immediately after refueling the tank/cell. Dripping leaks are usually found at fuel system plumbing connections. Leaks are caused by undertorquing or overtorquing lines, hoses, or fittings. The source of dripping leaks can usually be detected by operating the fuel transfer pump/boost pump to pressurize the fuel system. Intermittent leaks are most often caused by loose cell fittings, connections, or fuel quantity probes that are mounted on the high side of the tank/cell and usually leak when the aircraft is in a climb or descent. In some cases, servicing the fuel tank/cell to capacity may aid in locating these types of leaks.

The use of colored dye in fuel systems to detect "hidden" fuel leaks is one of the most practical means you can use in fuel system leak source analysis. The dyed fuel will leave a stain which can be traced back to the source of the fuel leak. The use of dyed fuel is particularly useful in checking for leakage near the engine's hot section or afterburner pigtail coupling where the high temperatures prevent the fuel from leaving a wet spot. When using a dye to aid in the troubleshooting of fuel leaks, a logbook entry in the miscellaneous history section of the aircraft logbook should be made so that the fuel color, resulting from the use of dye, can be disregarded in fuel sample analysis. Additionally, a similar entry should be made for aircraft serviced with dyed fuel. You should always select a dye color that will provide the highest visibility in the area where the leaking fuel is suspected. The use of 2 ounces of dye for each 100 gallons of fuel in the cell or tank is required. The appropriate information for ordering the dye can be found in Appendix A of NA 01-1A-35. The addition of unmixed dye to empty fuel systems should always be avoided because it can cause deterioration of the cell lining. The dye should always be added to the fuel, rather than fuel added to the dye. For more information and the correct procedures for the use of dyes in fuel system leak detection, refer

to the appropriate maintenance manual prior to adding any dye.

FUEL CELL REMOVAL AND INSTALLATION

The major source of damage to fuel cells that results in fuel cell rejection is improper handling during maintenance or inadequate preservation of the fuel cells. The removal and installation procedures for fuel cells will vary with each type of aircraft configuration. The appropriate maintenance instruction manual should be followed for the proper removal and installation procedures.

PACKAGING AND PRESERVATION

Once the cell is removed, to avoid any undue damage to the cell during handling, the following instructions apply:

1. Always transport the cell by a well-padded truck or dolly, or by hand carrying.
2. Never use any of the cell fittings for handholds while carrying the cell.
3. Never allow the cell to be dragged or rolled on the deck.
4. Prior to placing the cell on the deck, you should spread an appropriate barrier material on the area where the cell will be placed.
5. Never place the cell on a bench, pallet, or table where parts of the cell are allowed to overhang.
6. If the cell was removed during cold weather, you should warm the cell to at least 60 °F (16 °C) prior to collapsing or folding.
7. Never use unnecessary force or pressure to compress a collapsed cell into a small package. The undue pressure will produce sharp folds which cause damage to the cell.
8. Never allow the cell to be folded across or beside any of the cell fittings.
9. Never leave a self-sealing cell in a collapsed condition for a period longer than one hour. Bladder-type fuel cells may be left collapsed for an indefinite period of time, providing the cell is not walked on, severely creased, or otherwise subject to abuse.
10. Always install protective caps on the cell hanger receptacles while the cell is removed from the aircraft.

When a cell that has contained fuel is to remain empty for more than 72 hours, a thin coat of oil, MIL-L-6081, Grade 1010, should be applied to the inner liner. This process should be accomplished when the cell is installed, or when it is removed from the aircraft for storage. The oil will act as a temporary plasticizer, and it will prevent the inner liner from drying out and cracking. To get a uniform coat on the entire inner lining, you should use an oil-soaked cheesecloth to apply the preservative oil. Inaccessibility is a problem with some fuel cells and the only way to properly protect the cell is to apply the preservative by spraying. Pliocel-type bladder cells do not require internal preservation except when they are folded and stored for a period in excess of 2 weeks. If it becomes neccessary to preserve this particular type of cell, the inner lining must be coated with equal parts of glycerin, MIL-G-491, and water. A cheesecloth soaked with this solution should be used to apply the preservative. Fuel cells that are to be returned to storage until repairs can be accomplished at a later date should have a coating of oil, MIL-L-6082, Grade 1065, applied to the interior of the cell. The heavier type of oil will act as a preservative during the sustained period. Although complete coverage of the cell interior is necessary, the preservative oil should not be allowed to puddle in the bottom of the cell.

When uncrating a fuel cell, you must always follow the opening instructions on the crate or shipping container. These instructions are provided for your use to prevent possible damage to the cell and to preserve the crate/shipping container for future use. Before removing the cell from the container, you should ensure that a clean, smooth surface, larger than the cell itself, has been cleared and protected with an appropriate barrier material before unfolding the cell. Fuel cells that have been stored for a long period of time can shrink or become distorted. Cells in this condition will be difficult for you to install, and they often cause misalignment of the cell fittings with the aircraft fittings. To restore a shrunken or distorted fuel cell to its original

condition, you should soak the cell in water. The length of time required for soaking will normally depend on the condition of the cell. Normally, 72 hours is sufficient, as long as the water temperature remains at least 70 °F (21 °C). Soaking time can also be reduced by placing the cell in an air-circulating oven at a maximum temperature of 120 °F (49 °C) for approximately 4 hours, as long as a high humidity condition is maintained.

CHAPTER 2

POWER PLANT TROUBLESHOOTING

Efficient maintenance of any aircraft depends upon the operating and maintenance personnel's familiarity with the aircraft and its associated components. The aircraft engine offers no exception in this case.

Troubleshooting aircraft engines may be defined as the systematic and thorough analysis of the symptoms of engine malfunctions. Proper troubleshooting determines the proper corrective steps to be taken. Whenever irregular ground or in-flight operating characteristics are observed, the cause can usually be traced to the malfunction of the engine, an engine component, or in some cases, improper maintenance or operation of the engine.

It is essential that you have a thorough knowledge of the engine. You should know how it is designed to function and how it fulfills that function. You should be familiar with normal operating parameters of the engine, such as oil pressures, temperature, and consumption; fuel pressures and flows or temperatures; and exhaust gas temperatures. These functions should be known for all of the engine operating conditions. In addition to knowing the normal engine conditions, you should have a thorough understanding of the effect of local conditions on the engine, such as atmospheric temperatures and pressure, inlet ducting and tail pipe influences, fuel temperatures, and wind effect.

If you use the information covered in this chapter, it will help promote a more efficient maintenance effort. Efficient maintenance means preventing trouble before it arises. You can do this by recognizing abnormalities of the equipment and tracing them to their sources. By making the correct judgement before making corrections, you can prevent damage to the engine. All to often, several seemingly unrelated indications of malfunctioning can eventually be traced to a single source.

NOTE: It is often unsafe to assume that the engine is completely repaired when some obvious corrective measure has been taken to correct a malfunction. Never be hasty in assuming any conclusions. Do not confuse the significance of cause and effect. For example, low oil pressure, in itself, is not truly trouble. It is only an indication that a problem exists, the true cause of which is the trouble.

The preceding note is stressed to emphasize the importance of tracing an abnormal indication to its source, rather than being satisfied that restoration to a normal condition is accomplished by some obvious adjustment. Adjusting the oil pressure relief valve setting is not the only correction required to correct a low oil pressure discrepancy. Invariably, there is a reason for an abnormal engine indication. You should be sure of the reason and make sure that proper corrective measures have been accomplished before the discrepancy is signed off and the aircraft is released for flight. Proper corrective measures require the use of time-proven methods, not guesswork.

Discrepancies resulting from careless engine operation are often the hardest engine trouble to trace. The aircraft discrepancy book (ADB) and the VIDS/MAFs are invaluable troubleshooting tools. The type of flight and previous maintenance actions may give an indication of the engine's problem. Many man-hours of troubleshooting an engine discrepancy may be saved by first screening the ADB for prior maintenance that may attribute to the cause of the problem,

improperly performed maintenance, and any trend of prior malfunctions.

All aircraft maintenance activities are plagued by repeat discrepancies. These discrepancies show up repeatedly on the same aircraft, even after being signed off as previously corrected. There are many possible causes for repeat discrepancies, the most common is poor troubleshooting procedures.

Troubleshooting is the logical or deductive reasoning procedure used when determining what is causing a particular system malfunction. There are seven steps involved in good deductive troubleshooting. The steps are listed below.

1. Visual inspection
2. Operational check
3. Classify the problem
4. Isolate the problem
5. Locate the problem
6. Correct the problem
7. A final operational check to verify that the problem has been corrected

USE OF DIAGRAMS, DRAWINGS, AND CHARTS IN TROUBLESHOOTING

The diligent use of the applicable Maintenance Instructions Manual (MIM) is essential in preventing the use of poor troubleshooting procedures. The MIM for each aircraft provides troubleshooting aids that cover the seven steps listed in the previous paragraph. These manuals provide a variety of troubleshooting aids. Table 2-1 shows two examples of troubleshooting chart formats. These charts are organized in a definite sequence under each possible problem, according to the probability of failure and ease of investigation. These charts supply the trouble, probable cause, and the remedy for some of the more common malfunctions. In order to obtain maximum value from these charts, they should be used systematically with the aircraft manufacturer's recommendations.

The MIM also contains diagrams and drawings for use in troubleshooting. Diagrams of the various electrical circuits, fuel systems, and lubrication systems are very useful in helping to isolate discrepancies. Figure 2-1 shows a typical

Table 2-1.—Samples of Various Troubleshooting Charts

Trouble	Possible cause	Suggested remedy
1. Transfer fuel quantity indicator inaccurate.	a. Malfunction in indicator or probes; electrical circuit malfunction.	a. Check electrical circuit (sections VI and IX).
	b. Indicator not calibrated correctly.	b. Check calibration (section VI).
2. Aft fuselage cells fail to transfer fuel.	a. Electrical circuits out.	a. Check electrical circuits (section IX).
	b. Transfer booster pump failure, or lines obstructed.	b. Replace pump or clear obstruction.
	c. Main fuel low level float valves failed.	c. Replace low level float valves.
	d. Pressure shutoff valve failed.	d. Replace PSO valve.
	e. Fueling manifold malfunction.	e. Replace manifold.
	f. Fuel transfer switch not in "FUEL TRANS" position.	f. Move switch to "FUEL TRANS" position.

1. Turbine inlet temperature OFF flag is visible during all operations.

Release clamp and remove temperature indicator from instrument panel. Disconnect electrical connector. Is 28 volts d.c. indicated between pins B and C of connector? → YES → Replace indicator.

↓ NO

Check wiring for continuity. Is continuity indicated? → NO → Replace or repair defective wiring.

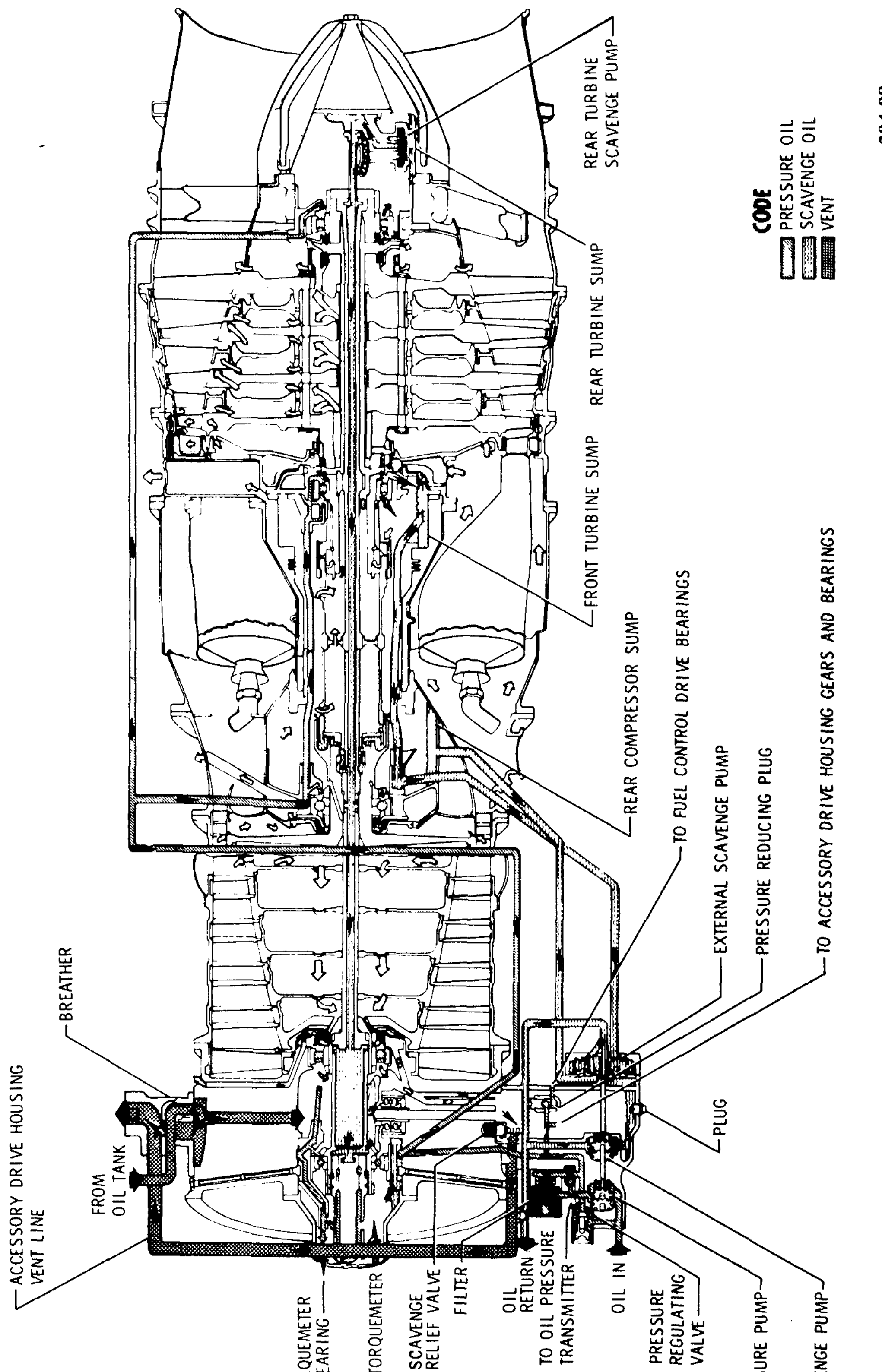

Figure 2-1.—Typical lubrication system drawing.

lubrication system drawing. Cutaway drawings show the internal construction of components, and exploded views show how the various parts of a component are assembled. Figure 2-2 shows a cutaway drawing and figure 2-3 shows an exploded view drawing. All of these various types of illustrations are important to you in troubleshooting. For a review on interpretations of drawings and diagrams, refer to the rate training manual, *Blueprint Reading and Sketching*, NAVEDTRA 10077 (Series).

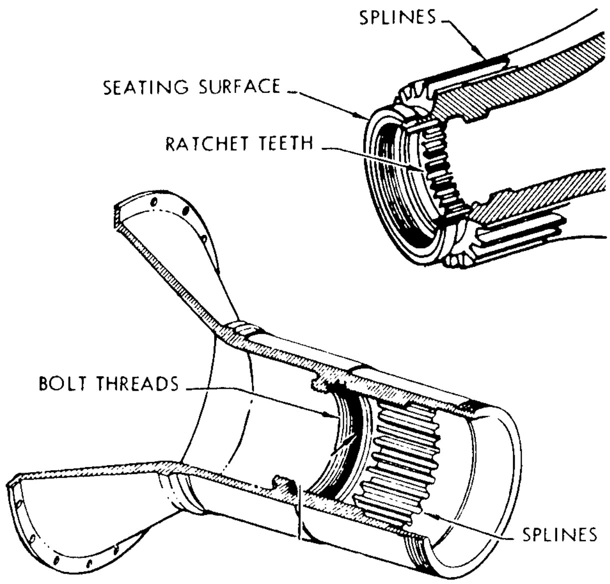

Figure 2-2.—Typical cutaway drawing.

SAFETY PRECAUTIONS

Safety in aircraft maintenance depends largely upon the quality of supervisory personnel. The standards of quality they establish are directly reflected in the quality of maintenance performed on the aircraft. The primary responsibility of the senior petty officer is to supervise and instruct others rather than to become totally engrossed in the actual maintenance effort. Attempts to perform both functions invariably result in inadequate supervision and a greater reduction in quality maintenance. As a supervisor, you must exercise mature and sound judgement when assigning personnel to maintenance tasks. Consideration of each person's ability, training, and experience is essential.

The considerations grouped under the term "human factors" are often overlooked in the maintenance evolution. These factors are very

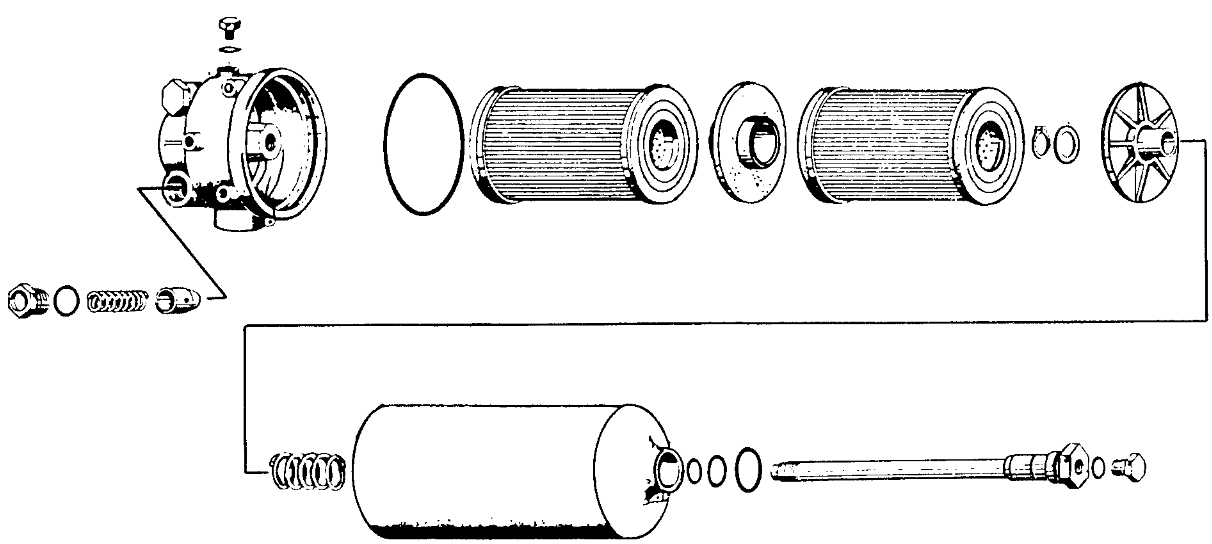

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Figure 2-3.—Typical exploded view drawing.

important because they determine if an individual is ready and physically able to perform quality work safely. Supervisory personnel should constantly be aware of conditions such as general health, physical and mental fatigue, morale, training and experience levels, and any other conditions that can contribute to varying degrees of poor and unsafe maintenance. Not only is it important that proper tools and protective clothing and equipment be available, but the supervisor must ensure these items are properly used any time their use is dictated by the particular maintenance functions.

It is the prime responsibility of every person connected with aircraft maintenance to try to discover and eliminate unsafe work practices. Accidents caused by such practices may not take place until a later date, and their severity cannot be predicted. The following items covered are general in nature, but they should be observed to prevent on-the-job accidents.

INTAKES

The air intake of an engine can develop enough suction to pull in hats, rags, loose clothing, and eyeglasses from pockets. All loose articles must be made secure or removed before working around the engine. In some engines, the suction is strong enough to pull a person up, or into the intake. On some aircraft configurations, auxiliary air doors are installed near the intake or underneath the aircraft. These doors can close in one-tenth of a second; therefore, tools or parts of your body should never be placed in these doors when the engine is running or when power is applied to the aircraft. If maintenance is required in this area, a safety jury strut must be installed or the operating mechanism disconnected.

EXHAUSTS

Tests have indicated that the carbon monoxide content of engine exhaust gas is low. However, other gasses are present which are irritating to the eyes and skin. Exposure to the exhaust gasses can cause watering or a burning sensation of the eyes. Respiratory irritation is less noticeable. Exposure to exhaust gasses should be avoided, particularly in confined spaces where the concentration of gasses may build up.

Two other important hazards of the engine exhaust are the high temperature and high velocity of the exhaust gasses from the tail pipe. High temperatures can be found up to several hundred feet from the tail pipe, depending upon the wind conditions. Near the aircraft, these temperatures are high enough to deteriorate bituminous pavements. Because of high temperatures, concrete aprons are suggested for run-up areas. When a jet engine is being started, excess fuel accumulates in the tail pipe. When the fuel ignites, long flames are blown out of the tail pipe.

During military power, the high velocity of the exhaust gasses may pick up and blow loose dirt or debris a distance of several hundred feet. When parking an aircraft for run-up, you should use caution to avoid personnel injury and/or aircraft damage. If jet engines are going to be used extensively, a blast deflector is recommended for use where there is not enough clear space available for disposition of the exhaust gas blast.

After engine operation, no work or inspection should be done in the exhaust section for at least one-half hour (preferably longer).

PROPELLERS

BEWARE OF PROPELLERS is the first precaution that must be observed by personnel working near propeller-driven aircraft. During high-power turnup, the velocity of the propeller wash may pick up and blow loose dirt and debris a distance of several hundred feet. Caution should be used in parking an aircraft for run-up to avoid personnel injury and aircraft damages.

ENGINE IGNITION

The ignition system, from the standpoint of the AD performing troubleshooting maintenance, is the system with the most frequent discrepancies. A clear understanding of the make-up and operation of the ignition system is essential. The use of the various pieces of test equipment, the ability to interpret

the readings from the test equipment, and the use of proper maintenance procedures will increase aircraft availability and decrease operating costs.

Because of the high voltage required for the engine igniter plugs, the ignition switch must be in the OFF position before you remove or check any of the ignition system components. You should always allow a sufficient period of time between the operation of the ignition system and the removal or checking of components to ensure the complete dissipation of energy from the ignition system. To obtain the maximum use of the test equipment and to thoroughly understand the ignition system, it is necessary for you to have an understanding of basic electricity. Refer to the appropriate technical publications for detailed information concerning the use of the test equipment.

ENGINE NOISE

Aircraft engines produce noise levels capable of causing temporary as well as permanent loss of hearing. Even short exposure to extreme levels of noise may result in damage to the eardrum. All personnel must use some means of hearing protection while working near aircraft. At a sound level of 90 decibels (dB) or more, ear protection must be used.

Noise can affect the ear mechanism in such a manner as to cause unsteadiness or inability to walk or stand. If engines are to be serviced from maintenance stands or platforms, they must be equipped with protective railings to prevent personnel from falling.

GENERAL TROUBLESHOOTING

The isolating and correcting of engine discrepancies should be accomplished by comparing symptoms with probable cause. Begin with the most obvious and proceed to the less likely causes. Do not overlook flight reports or previous engine history in the effort to troubleshoot and remedy the discrepancy. A combination of several small maladjustments or malfunctions may contribute to make a complex discrepancy. Table 2-2 lists some of the general conditions that may be encountered.

ENGINE SECTION TROUBLESHOOTING

The turbojet engine is used as an example in this section. You must remember that troubleshooting techniques and procedures will vary with each particular aircraft engine. The engine troubleshooting procedures covered in this section are used as an example only.

The basic turbojet engine is composed of four sections—the compressor section, the combustion chamber and turbine section, the accessory section, and the afterburner section. (See figure 2-4.)

COMPRESSOR SECTION

The compressor section of the tubojet engine is subject to a variety of service troubles, especially damage from foreign matter passing through the compressor. Small pebbles, nuts, bolts, and washers can cause severe damage to the compressor rotor blades and stator vanes. Damage severe enough to warrant complete overhaul of the engine can result from the ingestion of foreign

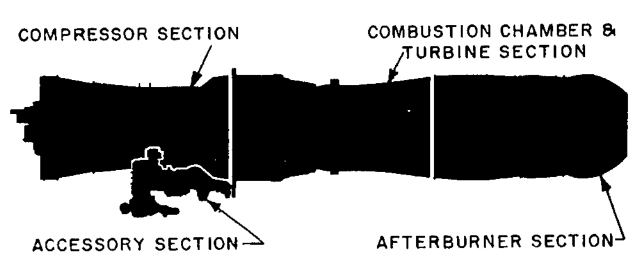

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Figure 2-4.—Gas turbine engine sections.

Table 2-2.—Troubleshooting Chart of Engine General Troubles

Trouble	Probable cause	Investigation	Remedy
Compressors fail to rotate during attempted start	Inadequate or no air supply to starter.	Air supply source.	Provide adequate air supply to starter.
	Internal rotating parts binding.	Check rotor for freedom of rotation.	Replace engine.
	Sheared starter jaw or sheared starter drive in N_2 gearbox.	Starter rotation.	Replace faulty components.
Engine fails to "light-off" when power lever is advanced to idle	Main power switch off.	Check power switch for "ON" position.	
	Defective ignition system.	Turn on system and listen for igniter plug operation.	Refer to IGNITION SYSTEM TROUBLESHOOTING.
	No fuel to engine.	Fuel shutoff lever not fully open.	Adjust linkage.
		Wrong grade of fuel or contaminated fuel.	Drain tanks and refill with the proper fuel.
		Obstructions in fuel pump inlet line or filter.	Clean lines and filter.
		Fuel tank boost pump inoperative.	Repair or replace boost pump.
		Obstructions in fuel tank vent lines.	Clean lines.
Engine "lights-off" but fails to accelerate to idle	Starter cut-out too low.	Check auxiliary power unit and/or starter.	Repair or replace.
	Inadequate air supply.	Air supply source.	Provide adequate air supply to starter.
	Loose or broken burner pressure sense line.	Check sense line for security or damage.	Tighten or replace sense line.
	Burner pressure limiter stuck open.		Replace fuel control.

Table 2-2.—Troubleshooting Chart of Engine General Troubles—Continued

Trouble	Probable cause	Investigation	Remedy
Engine "lights-off" but fails to accelerate to idle--Continued	Fuel control acceleration schedule out of limits.		Replace fuel control.
	Fuel control linkage improperly rigged.	Angle of pointer at fuel control when power lever is in idle.	Correct rigging of linkage.
Failure of engine to decelerate properly	Fuel control rigging error.	Inspect linkage.	Adjust linkage.
	Malfunctioning fuel control		Replace fuel control.
Fluctuating rpm	Contaminated fuel.		Drain tanks and refill with proper fuel.
	Defective instrument and/or instrument circuits.	Check instrument for accuracy. Check the electrical circuits for abnormal resistance and continuity.	Repair or replace defective components.
	Compressor bleed valves malfunction.	Observe position of compressor bleed valves during start.	Clean the lines to the pressure ratio control. Check the valves for freedom of movement.
	Fuel tank vent obstructed.	Check for obstruction.	Clean lines.
	Clogged fuel filter.	Remove and inspect fuel filter.	Clean or replace.
Inability to obtain maximum fuel flow	Incorrect trim.	Check trim.	Replace fuel control if trim cannot be obtained.
	Incorrect travel of power lever linkage.	Power lever linkage for proper travel between the lever and fuel control.	Readjust or replace linkage.

Table 2-2.—Troubleshooting Chart of Engine General Troubles—Continued

Trouble	Probable cause	Investigation	Remedy
Inability to obtain maximum fuel flow--Continued	Malfunctioning fuel control.	Check fuel flow through flowmeter.	Replace fuel control.
	Clogged fuel filters.	Remove and inspect the fuel filters.	Clean or replace.
Engine slow in accelerating	Defective fuel control.	Possible broken compressor inlet temperature capillary tube to fuel control.	Replace fuel control.
Hot start	Defective ignition.		Refer to IGNITION SYSTEM TROUBLESHOOTING.
	Insufficient cranking speed.	Auxiliary power unit and/or starter.	Repair or replace.
	Accumulation of fuel in the engine.	Check the drain valve on the combustion chamber case.	Remove excess fuel from engine and refer to FUEL SYSTEM TROUBLESHOOTING.
Low exhaust duct temperature	Improper trim.		Retrim.
	Malfunctioning fuel control.	Check for proper trim.	Replace the fuel control if trim speed cannot be attained.
	Defective thermocouple.	Check the thermocouple leads and instruments.	Repair or replace defective leads or instrument.
Engine roughness or vibration	Interference between turbine rotor inner air seals and the inner seal rings.	Check for scraping noise as engine slows down after closing the fuel pressurizing and dump valve.	Replace the engine.

Table 2-2.—Troubleshooting Chart of Engine General Troubles—Continued

Trouble	Probable cause	Investigation	Remedy
Engine roughness or vibration--Continued	Main bearing failure.	Check the oil strainer for metal particles.	Replace the engine.
	Erratic fuel flow.		Replace fuel control.
	Combustion flame pattern incorrect.	Check for faulty or dirty fuel nozzles, collapsed or damaged combustion chambers.	Repair or replace nozzles or chambers.
High exhaust duct temperature	Engine over trimmed.		Retrim.
	Insufficient air.	Check the air intake for obstructions.	Remove obstructions.
	Defective thermocouple leads, or temperature gage.	Check the thermocouple leads and instruments.	Repair or replace thermocouple leads and instruments.

Table 2-3.—Compressor Troubleshooting Chart

Troubles	Probable causes and remedies
Nicks, dents, and cracks on compressor rotor blades, compressor stator vanes. NOTE: Passage of some foreign objects can easily cause strike damage to the engine.	Passage of foreign matter. Assure that intake duct and operating area are always clean of foreign matter. Use protective screens. Cracks on compressor rotor blades and compressor stator vanes are also caused by operating stresses. Repair, replace, or reject damaged compressor blades and stator vanes in accordance with applicable technical instructions.
Rubbing noise in compressor---	Excessive blade root looseness (radial) causing tip of blade to rub against compressor housing. Blade stretch. Blades working out of compressor rotor in an axial direction and rubbing against stator vane assemblies. Warped compressor stator vane assemblies rubbing against compressor rotor. Excessive compressor rotor axial clearance. Reposition, replace, repair, or reject in accordance with applicable technical instructions.
Engine overspeed---	Malfunctioning fuel control. Improper rigging of fuel control linkage. High speed stop improperly set. Refer to applicable technical instructions concerning engine overspeed. Generally, when the maximum rpm specified by the manufacturer has been exceeded, the engine is sent to overhaul due to the high centrifugal loads imposed upon the compressor and other rotating parts.

matter. Table 2-3 lists some of the common troubles experienced with typical compressors.

COMBUSTION CHAMBER AND TURBINE SECTION

Although high temperatures take place in the combustion chamber and turbine section, few major service troubles are encountered when maximum temperature and maximum RPM limits are closely monitored. Hot starts, overtemperatures, and exceeding maximum RPM will cause extensive service troubles in the combustion chamber and turbine section. Service troubles common to the combustion chamber and turbine section of an axial-flow engine are listed in tables 2-4 and 2-5.

Table 2-4.—Axial-Flow Combustion Chamber Section Troubleshooting Chart

Troubles	Probable causes and remedies
Cracks, dents, distortion, warpage, hotspots, erosion, and deterioration in combustion chamber section.	Passage of foreign matter. Pieces breaking off combustion chamber and causing damage as they pass rearward. Improper torque. Malfunctioning fuel nozzles. Excessive heat concentration due to carbon accumulations. Normal wear. Certain types of cracking and burning deterioration resulting from thermal stresses may be found on new engines. NOTE: The majority of discrepancies occur in the early stages of operation, and further progression may be expected to proceed at a greatly reduced, if not negligible, rate. Always refer to applicable technical instructions to determine whether or not defective parts discovered can be repaired or continued in service, or whether the unit or part should be rejected.

Table 2-5.—Axial-Flow Turbine Section Troubleshooting Chart

Troubles	Probable causes and remedies
Cracks, dents, distortion, erosion, and localized overheating on turbine nozzle guide vanes.	Passage of foreign matter. Pieces breaking off combustion chamber. Improper torque of attaching bolts. Engine operating overtemperature. Malfunctioning fuel nozzles. Normal wear. Repair, replace, or reject in accordance with applicable technical instructions.
Cracks, dents, nicks, distortion, and warpage on turbine blades and turbine wheel or wheels. NOTE: Turbine blades and turbine wheels are also subject to blade or wheel growth (stretch) when excessive rotational or excessive temperatures are attained.	The above probable causes and remedies also apply here.
Localized overheating, warpage, and cracks on turbine case.	Malfunctioning fuel nozzles. Bowed, broken, or distorted turbine stator vanes. Improper torque of attaching bolts. Repair, replace, or reject in accordance with applicable technical instructions.

Table 2-6.—Afterburner Troubleshooting Chart

Trouble	Probable Cause	Investigation	Remedy
Afterburning does not take place when throttle is placed in afterburner position.	Defective afterburner switch.	With throttle full forward and in afterburner position, check continuity between common and normally open terminals on afterburner switch.	Replace switch.
	No power to afterburner switch.	Check for voltage between afterburner fuel control lead and ground.	
	Defective solenoid on afterburner fuel control.	If the preceding checks indicate that power is available at solenoid, solenoid is defective.	Replace afterburner fuel control.
	Defective afterburner igniter.		Replace afterburner igniter.
	Afterburner emergency shutoff valve linkage out of adjustment.	Check linkage.	Adjust linkage.
	Igniter filter clogged.	Check filter.	Clean filter element.
Exhaust nozzle fails to open or close when afterburning is initiated or terminated.	Defective exhaust nozzle control.		Replace exhaust nozzle control.
	Misadjusted nozzle flaps.	Visually check operation of nozzle with engine running. Observe position of all nozzle flaps during transition from nonafterburning to afterburning operation.	Adjust nozzle linkage.
Turbine exhaust temperature, rpm, or engine pressure ratio deviate more than acceptable.	Defective afterburner fuel control.	If nozzle operates correctly and basic engine operation is satisfactory, afterburner fuel control is defective.	Replace afterburner fuel control.

AFTERBURNER SECTION

Although relatively simple in construction, the afterburner section requires constant observation. Generally, the use of the afterburner is of short duration, but during use, it is subjected to consistently high temperatures. Common service troubles of the afterburner are listed in table 2-6.

ACCESSORY SECTION

Location of the accessory section will vary on different models of gas turbine engines. Table 2-7 lists some of the common service troubles of the axial-flow engine accessory section.

AIR SYSTEM

All personnel should clearly understand that any obstruction or interruption of the air as it moves through the engine will affect the entire operation of the engine. Entrance of foreign matter into the air system is one of the main causes of service trouble. When foreign matter enters the axial-flow compressor, it generally causes dented, cracked, and torn or broken compressor rotor blades and compressor stator vane damage. As the foreign matter passes rearward, it causes improper combustion, blockage of cooling air passages, and physical damage to the combustion chamber and turbine section, and the afterburner section.

FUEL SYSTEM

The fuel system of the gas turbine engine begins at the engine-driven fuel pump and ends with delivery of fuel to the combustion chambers through fuel nozzles in the form of highly atomized spray. Common service troubles of the fuel system are wrong types of fuel, water or other foreign matter in the fuel, defective fuel-boost pumps, and clogged fuel filters.

LUBRICATION SYSTEM

The use of the proper grade of oil and cleanliness observed when replenishing the oil supply are absolute requirements to avoid unnecessary lubrication system troubles. Gas turbine engines have few moving parts, but the speed at which the parts move, especially the rotor (generally between 8,000 and 12,000 RPM), requires constant lubrication to the rotor bearings. Oil starvation for a short period of time can result in having to remove the engine for overhaul. Some of the common

Table 2-7.—Engine Accessory Section Troubleshooting Chart

Troubles	Probable causes and remedies
Chafed, broken, or loose electrical leads.	Improper installation. Damaged during removal or installation of engine. Repair or replace in accordance with applicable technical instructions.
Cracks, dents, loose lines, corrosion, and evidence of leakage.	Hard landings. Improper torque. Improper safetying. Improper painting or preservation procedure. Missing or broken gaskets or O-rings. Repair or replace in accordance with applicable technical instructions.
Cracked, corroded, loose, or leaking flange-mounted accessories.	The above causes and remedies apply.

Table 2-8.—Axial-Flow Engine Lubrication System Troubleshooting Chart

Trouble	Probable cause	Investigation	Remedy
High oil temperature	Insufficient oil in tank.	Check oil level in tank.	Fill tank.
	Clogged oil strainer.	Remove and inspect oil strainer.	Clean or replace.
	Bearing failure	Check the oil and strainers for metal particles.	Remove the engine.
	Defective oil pump.	Check pump operation with a master gage.	Repair or replace oil pump.
Low oil temperature	Oil temperature gage not functioning properly.	Check oil temperature gage and sensing unit for accuracy.	Replace or repair oil temperature gage.
	Thermostatic valve in the fuel coolant oil cooler not functioning.	Remove and check the cooler for proper operation.	Replace the oil cooler.
High or low oil pressure	Oil pressure relief valve malfunctioning.	Check for free movement of relief valve.	Repair or replace, adjust valve if necessary.
	Main oil pump malfunction.		Replace main oil pump.
	Oil pressure gage not functioning properly.	Check oil pressure gage with master gage.	Replace oil pressure gage.
Excessive oil consumption	Oil leakage.	Visually inspect all external tubing and case parting flanges for oil leaks.	Tighten connectors. Replace seals or gaskets as necessary.
	Loose oil tank cap.		Tighten cap.
	Breather pressurizing valve not functioning properly.	Remove and check the valve for proper operation.	Replace breather pressurizing valve.
Excessive oil pressure	Defective oil pressure transmitter and/or indicator.	Replace instrument with one of known accuracy and recheck pressure.	Replace instrument.

Table 2-8.—Axial-Flow Engine Lubrication System Troubleshooting Chart—Continued

Trouble	Probable cause	Investigation	Remedy
Excessive oil pressure--Continued.	Misadjusted relief valve.	If pressure indicating system is satisfactory and engine operational check does not disclose any apparent malfunctioning, the relief valve can be adjusted.	Adjust relief valve.
	Relief valve stuck closed.	Check relief valve for freedom of movement.	Replace valve.
Low or fluctuating oil pressure	Insufficient oil supply.	Check oil level.	Service oil system.
	Clogged or dirty strainer.	Pull oil strainer.	Clean strainer.
	Relief valve adjusting screw backed off.	Check adjusting screw locknut.	Adjust relief valve and tighten locknut.

service troubles of an axial-flow lubrication system are listed in table 2-8.

NAVY OIL ANALYSIS PROGRAM (NOAP)—METAL PARTICLE IDENTIFICATION

Metal particles found on the oil strainer screens and in the oil sumps are usually the first evidence of a possible failure of a part within the engine. The presence of any metal particles on the oil screen or in the sump is not necessarily an indication that the engine is not suitable for further service. The kind, form, quantity, and the source of the foreign material found will dictate whether or not an engine is serviceable. The metals usually found are steel, tin, aluminum, silver, copper (bronze), chromium, indium, cadmium, nickel and tin cadmium combinations. Occasionally, and with some experience on your part, a visual inspection as to color and hardness will help you to identify the metal particles. The particles of metal found in an engine may be a granular or flake form.

When a visual inspection does not positively identify the metal, the kind of metal may be determined by a few simple tests. These tests are performed with a permanent magnet, an electric soldering iron, and approximately two ounces each of concentrated hydrochloric (muriatic) acid, concentrated nitric acid, chromic acid, and sodium or potassium hydroxide.

CAUTION: Always use extreme care when handling acids.

The following test procedures are recommended for determining the type of metal particles:

1. Steel and nickel. These metal particles can be isolated by using a permanent magnet.
2. Tin. Tin particles can be distinguished by their low melting point. Use a clean soldering iron, heated to 500 °F (260 °C) and tinned with a 50-50 solder (50 percent tin an 50 percent lead). A tin particle dropped on the soldering iron will melt and fuse with the solder.
3. Aluminum. Aluminum particles can be determined by their reaction with hydrochloric acid. When a particle of aluminum is dropped into the hydrochloric (muriatic) acid, it will "fizz" with a rapid emission of bubbles, and the particle will gradually disintergrate. Aluminum particles will also dissolve rapidly and form a white cloud in a strong caustic solution (sodium or potassium hydroxide). Silver and copper (bronze) do not noticeably react with hydrochloric acid.
4. Silver and copper (bronze). Silver and copper (bronze) may be differentiated by their respective reactions in nitric acid. When a silver particle is dropped into nitric acid, it will react with the acid, slowly producing a whitish fog in the acid. When a particle of copper (bronze) is dropped into the nitric acid, it will react rapidly with the acid. This reaction produces a bright, bluish-green cloud in the acid.
5. Chromium. These particles may be determined by their reaction to hydrochloric acid. When a chromium particle is dropped into concentrated hydrochloric acid, the acid will develop a greenish cloud.
6. Cadmium. Cadmium particles will dissolve rapidly when dropped into a 5 percent solution of chromic acid.
7. Tin Cadmium. These particles will dissolve rapidly when dropped into a 5 percent solution of chromic acid. The tin content will cause a clouding of the solution.

To make sure the metal particles found in the oil are of an acceptable quantity for the engine to remain in service, refer to the applicable maintenance manual for the limits allowed on metal particles for each particular engine.

The Navy Oil Analysis Program (NOAP) provides a diagnostic technique to monitor and diagnose equipment or oil condition without the removal or extensive disassembly of the equipment. It is mandatory for all activities that operate aeronautical equipment to participate in this program unless the activity has been specifically relieved of this responsibility by the type commander or the cognizant field activity (CFA). The CFA provides information concerning the sampling points, sampling techniques, and sampling intervals for all Navy equipment for which oil analysis is mandatory. The CFA establishes and maintains sampling information for the Maintenance Requirements Cards (MRCs) or MIMs for the respective equipment or weapon systems.

Spectrometric oil analysis is a diagnostic maintenance tool and is used by the military services to determine the type and amount of wear metals in lubricating fluid samples. Engines, gearboxes and hydraulic systems are the types of equipment most frequently monitored. The presence of unusual concentrations of an element in the fluid sample indicates some abnormal wear of the equipment. Once the abnormal wear is verified and pinpointed, the equipment may be repaired or removed from service before a major failure of the fluid covered component occurs. This philosophy enhances personnel safety and material readiness at a minimum cost, and serves as a decisive tool in preventive maintenance action. Thus, worn parts may be replaced prior to a catastrophic failure.

WEAR METALS

Wear metals are generated by the relative motion between the metallic parts in moving contact in a mechanical system, even though lubricated. For normally operating equipment, the wear metal is produced at a constant rate. This rate is similar for all normally operating equipment of the same model. Any condition that alters the normal relationship or increases the normal function between the moving parts will accelerate the rate of wear and increase the quantity of wear metal particles produced. If the condition is not discovered and corrected, the deterioration will continue to increase causing secondary damage to other parts of the assembly. This can result in the eventual failure of the entire assembly and loss of the equipment. New or newly overhauled

assemblies tend to produce wear metal in high concentrations during the initial break-in period.

IDENTIFICATION OF WEAR METALS

The wear metals produced in fluid lubricated mechanical assemblies can be separately measured, in extremely low concentrations, by spectrometric analysis of fluid samples taken from the assembly. Two methods of spectrometric oil analysis are currently used to measure the quantity of various metals.

1. Atomic Emission—The emission spectrometer is an optical instrument used to determine the concentration of wear metals in the lubricating fluid. This analysis is accomplished by subjecting the sample of fluid to a high-voltage spark, which energizes the atomic structure of the metal elements and causes the emission of light. The emitted light is then focused into the optical path of the spectrometer and separated by wavelength, converted to electrical energy, and measured. The emitted light for any element is proportional to the concentration of wear metal suspended in the lubricating fluid.
2. Atomic Absorption—The atomic absorption spectrometer is an optical instrument also used in determining the concentration of wear metals in the lubricating fluid. The fluid sample is drawn into a flame and vaporized. The atomic structure of the elements present become sufficiently energized by the high temperature of the flame to absorb light energy. Light energy having the same characteristic wavelength as the element being analyzed is radiated through the flame. The resultant light is converted to electrical energy and measured electronically. The amount of light energy absorbed by the elements in the flame is proportional to the concentration of wear metals suspended in the lubricating fluid.

NOTE: The spectrometric fluid analysis method is effective only for those failures that are characterized by an abnormal increase in the wear metal content of the lubricating fluid. This is particularly true of failures that proceed at a rate slow enough to permit corrective action to be taken by the operating activity after receipt of notice from the laboratory.

The value of a spectrometric analysis and the later use of this analysis by the evaluator is based on the assumption that the oil sample is representative of the system from which the sample was taken. Occasionally, by accident, samples from one component may be substituted for another, resulting in what may at first appear to be a developing wear condition for one of the components. A sudden increase of wear metal in one component and a decrease in another should be considered as a problem related to sample error (misidentifying a sample as an engine sample when it was actually a transmission sample).

SAMPLING TECHNIQUES

Normally, the sampling interval is based on the average wear rate of a given piece of equipment and the hazards related to potential equipment failure. Sampling intervals should be as close as possible to specified times without interfering with scheduled operations. Generally, the sampling intervals should not vary more than ±20 percent of that time specified for each type/model/series of equipment as modified by the appropriate equipment managers.

NOTE: Refer to the applicable scheduled maintenance or periodic inspection document for the specific routine sampling interval and specific sampling instructions for each type/model/series of equipment being sampled.

Each operating activity participating in the NOAP must ensure that all routine samples are taken properly and at the prescribed intervals. In addition to the routine samples, each operating activity is required to submit special samples under the following conditions:

1. When samples are requested by the CFA or by the laboratory.
2. When the activity is so directed by the unit maintenance officer to check out suspected deficiencies.
3. When an operation results in abnormal conditions such as malfunction of the oil lubricated component, damage to the oil lubricating system, excessive engine oil loss, and low, fluctuating, or zero oil pressure.

4. Before and after the replacement of major oil lubricating system components.

5. During and at the completion of a test cell run. If the repaired or suspect unit is operated on oil previously used in the test cell system, a sample must be taken before and after the completion of the test cell run.

6. After the final test on an aircraft that is undergoing rework or scheduled depot level maintenance, and after installations of new/overhauled engines or engines repaired by AIMD.

7. Following all accidents, regardless of cause and resulting damage, these samples must be taken by any means possible to obtain a representative sample.

There are two basic methods of taking a fluid sample: (1) the dip tube technique and (2) the drain technique, which is used only when it is impossible or very difficult to obtain a dip tube sample. Special sampling procedures for equipment that cannot be sampled by either of the two basic techniques must be established in periodic inspection or preventive maintenance documentation governing the use of such equipment.

Dip Tube Sampling

The following procedures should be followed when using the dip tube method for obtaining a fluid sample:

1. Remove the filler cap from the oil tank and open the sample bottle.

2. Use a sampling tube of the correct length, grasp the tube at one end and lower it into the tank through the filler neck until only the upper end protrudes. (See figure 2-5, views A and B.)

3. Allow the lower end of the tube to fill with oil, then close the upper end with your thumb or finger. Withdraw the tube and drain the trapped oil into the sample bottle. (See figure 2-5, views A and B.) Repeat this operation until the bottle has been filled to approximately one-half inch from the top.

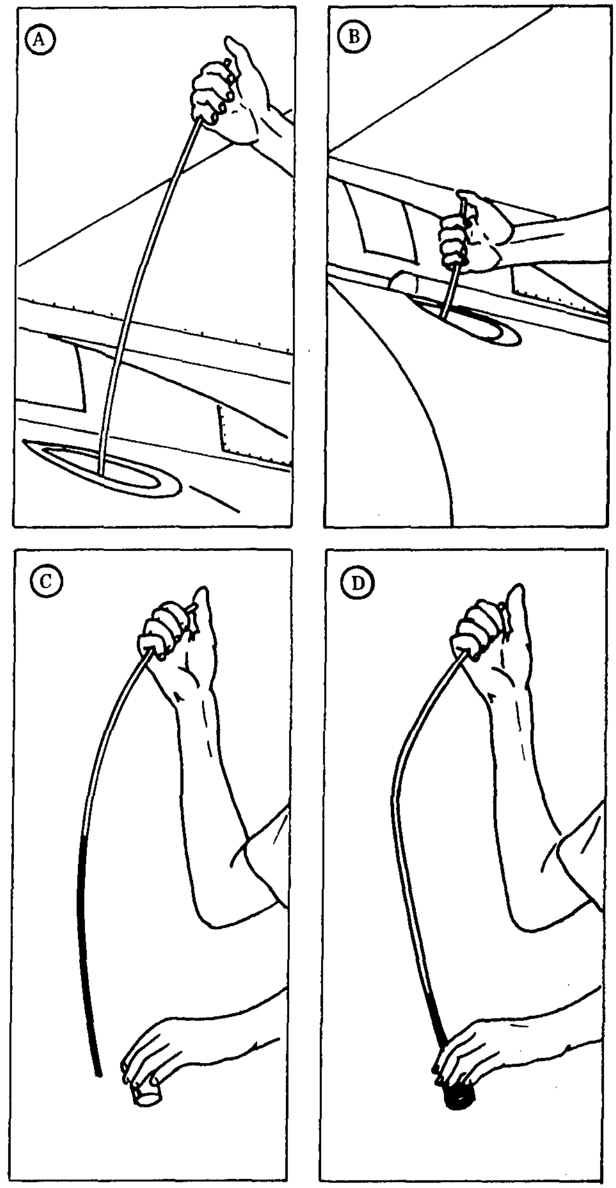

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Figure 2-5.—Dip tube sampling.

WARNING: Do not use mouth suction to fill the sampling tube. Many oils and fluids are highly toxic and may cause paralysis and/or death.

4. Replace the bottle cap and tighten it to prevent leakage of the sample. Replace the cap on the tank and discard the sampling tube.

Drain Sampling

When using the drain sampling method for obtaining a fluid sample, you should use the following procedures:

1. Open the sample bottle.
2. Open the drain outlet in the bottom of the tank, sump, case, or drain port, and allow enough oil to flow through to wash out accumulated sediment. (See figure 2-6, view A.)

NOTE: For shipboard equipment, samples should be taken from a petcock on the oil pump discharge line while the engine is running at normal operating temperature.

3. Hold the sample bottle under the drain and fill to approximately one-half inch from the top. (See figure 2-6, views B and C.) Close the drain outlet.
4. Replace the bottle cap and tighten it enough to prevent leakage.

In addition to ensuring that proper sampling techniques are followed, the activity is responsible for making appropriate entries in the equipment logbook, or in the case of transmissions and gearboxes, the section of the SRC card labeled "significant repair." Entries are necessary when oil analysis is initiated, terminated, or the monitoring laboratory is changed. When equipment is removed or transferred, a specific notation is made of the NOAP analytical status at the time of removal or transfer. The operating activity is also required to provide special reports or feedback information as requested by the oil analysis laboratory or the CFA.

For complete information concerning the NOAP, refer to NAVMATINST 4731.1, which covers program objectives and responsibilities for operation. The *Joint Oil Analysis Program Laboratory Manual*, NAVAIR 17-15-50, will provide instructions for sampling and filling out the sample request form (DD Form 2026). Instructions also include procedures for submitting samples to the assigned supporting laboratory, evaluation criteria, and the procedures for obtaining special technical assistance as required.

The Joint Oil Analysis Program Technical Support Center, located at the Naval Air

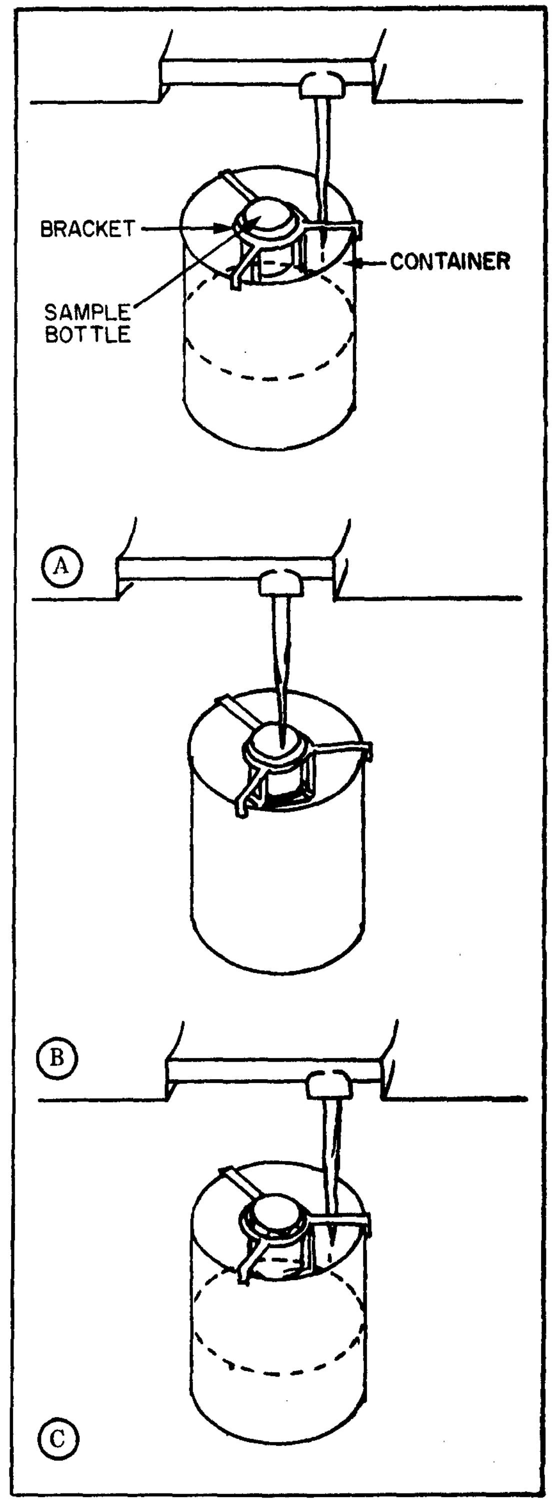

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Figure 2-6.—Taking drain samples.

Station, Pensacola, Florida 32508, is the center of technical expertise for the entire oil analysis program. The center is responsible for the following:

1. Providing on-site maintenance service for all analysis spectrometers

2. Developing and providing evaluation criteria to all analysis laboratories

3. Providing spectrometer oil calibration standards

4. Certifying oil analysis laboratories

5. Providing on-site oil analysis training

6. Developing and updating the Joint Oil Analysis (JOAP) Laboratory Manual

7. Providing consolidated historical or comparative oil analysis data to the equipment CFA in support of maintenance engineering/mechanical malfunction analysis

CHAPTER 3

POWER PLANT REPAIR

The purpose of this chapter is to familiarize you with the different engine sections and some of the types and authorized repair limits for these sections. Repair requirements are different for each particular engine. Before any type of maintenance is performed, you must be familiar with the step-by-step procedures contained in the current technical publication for the particular engine.

As a senior AD, you may be assigned duties other than organizational-level maintenance. It is important that you become familiar with the repair capabilities and functions of an intermediate-level maintenance activity.

INTERMEDIATE MAINTENANCE DEPARTMENT

Intermediate maintenance applies to those maintenance functions normally performed in centrally located facilities for support of the operating units. The facilities are designated as aircraft intermediate maintenance departments (AIMD).

The primary purpose of the intermediate-level maintenance activity is to support and supplement the work of organizational maintenance activities. Squadron personnel assigned to the intermediate-level activity, ashore or afloat, are assigned to perform the total work (within their skills) of the intermediate activity and not just the work related to support of the squadron from which they were assigned.

The following paragraphs cover some of the procedures used in the Three-Degree Gas Turbine Engine Repair Program by an intermediate maintenance activity.

THREE-DEGREE GAS TURBINE ENGINE REPAIR PROGRAM

The Gas Turbine Engine Maintenance Program was formed under the three-degree concept as specified in OPNAVINST 4790.2 (Series). Under this concept, each engine's intermediate maintenance manual defines specific engine maintenance actions as either first-, second-, or third-degree functions. These functions are determined largely by degree of difficulty and frequency of repair.

FIRST-DEGREE REPAIR

First-degree repair is defined as the repair of a damaged or nonoperating gas turbine engine and its accessories or components to an acceptable operating condition when the repair includes compressor rotor replacement and/or disassembly to the extent that the compressor rotor could be removed. Additionally, any repair that goes beyond that authorized for a second-degree activity, but not to the extent required to be performed at depot level, is defined as first-degree repair.

NOTE: The terms "first-degree repair" and "complete engine repair" (CER) are synonymous. CER is used primarily with older engines that are not included in the three-degree program.

SECOND-DEGREE REPAIR

Second-degree repair is the repair of a damaged or nonoperating gas turbine engine and

its accessories or components to an acceptable operating condition. Second-degree repairs will normally include the repair/replacement of turbine rotors and combustion sections, including afterburners; the replacement of extremely damaged, deteriorated, or time-limited components, gearboxes, or accessories; and minor repairs to the compressor section. The repair or replacement of reduction gearboxes and torque shafts of turboshaft engines and compressor fans of turbofan engines (which are considered repairable within the limits of the applicable intermediate maintenance manual) is also defined as second-degree repair.

THIRD-DEGREE REPAIR

The third-degree repair encompasses major engine inspections and the same gas turbine engine repair capability as second-degree maintenance. Certain functions that require high maintenance man-hours and are of a low incidence rate are excluded.

NOTE: The functions described in the above paragraphs represent broad generalities. Refer to the appropriate engine maintenance plan or intermediate maintenance manual to determine the degree of assignment for specific repair functions, as these vary from engine to engine.

LOCAL REPAIRS TO ENGINES

You, as the senior AD, must have the ability to determine the feasibility of local repairs to engines and components. You must make sure the proper manpower, equipment, and tools are on hand for accomplishing the job. You should keep in mind the following considerations: (1) What are the operating commitments of the supported activity? (2) Can the engine or component be repaired in a minimum amount of time, or will it be a time-consuming repair that will hold the aircraft out of flight status for an unusually long period of time?

Aircraft maintenance must be accomplished at the lowest level of maintenance, as established by OPNAVINST 4790.2 (Series), but maximum readiness must be maintained. As previously discussed, the time element must be considered in any maintenance task. If it is determined the task will be a high-time consumer, the engine or component should be replaced. The removed engine or component is returned to supply to be repaired at a higher degree of maintenance, or it is removed from service.

All of these factors must be considered in determining the feasibility of repairing a jet engine or component locally. Technical publications must be consulted for the repair limits and the procedures to be used. The feasibility of repair rests with the supervisor, who must operate within the guidelines and directives established by higher authority. The level of maintenance required for each maintenance task is prescribed in the appropriate directives. Each level of maintenance should have the tools, equipment, and personnel to do the job.

CLEANING

As soon as the engine or component has been disassembled, all of the parts should be analyzed and cleaned thoroughly. Correct and thorough cleaning of the engine or component is of the utmost importance to successful inspection, to field repair, or to satisfactory operation after field repair. Normally, an emulsion cleaner is used because it is neutral and noncorrosive. Before cleaning and using any type of cleaning material, follow the applicable technical instructions carefully to prevent damage to the parts being cleaned or injury to personnel doing the cleaning. During the disassembly and inspection of the parts, a list of new parts, packings, and O-rings needed for reassembly should be made and a demand on supply should follow.

WELDING

Welding is permissible on some parts of the jet engine. Refer to the applicable technical

instructions before attempting to weld an engine or component.

GRINDING AND BLENDING OF PARTS

The grinding and blending of nicks and scratches must be accomplished in strict compliance with the applicable technical instructions. Minor nicks and scratches can be removed by hand filing and blending.

HOT SECTION HARDWARE

Correct engine or component reassembly procedures require that particular attention be paid to the material requirements for the nuts and bolts used in the hot section of the jet engine. In these areas, where parts must be made of material that is resistant to high operating temperatures, special heat resistant alloys are employed. During a reassembly of the engine or component, the properly coded part must be reassembled in its original location, if serviceable.

MARKING OF HOT SECTION COMPONENTS

Certain materials may be used for temporary marking during assembly and disassembly. Layout dye (lightly applied) may be used to mark parts that are directly exposed to the engine gas path, such as turbine blades and disks, turbine vanes, and combustion chamber liners. A felt tip or grease marking pencil may be used for parts that are not directly exposed to the gas path. This type of mark is easily obliterated and has less durability.

Any temporary marking method that leaves a heavy carbon deposit or a detrimental deposit of copper, zinc, lead, or similar residue may cause subsequent carburization or intergranular attack when the part is subjected to intense heat. Always avoid the use of such methods unless the marking is completely removed before the part is subjected to intense heat.

ENGINE BREAKDOWN

When the engine or component is delivered to an AIMD activity, a total inspection is performed. All the repairs required to place the engine component back in an RFI (ready for issue) status are accomplished.

COMPRESSOR SECTION

Most intermediate-level maintenance activities, depending on their assigned maintenance level capability, are responsible for the replacement of compressor sections and the repair of those compressor blades in the later compressor stages that cannot be serviced without the removal of the compressor halves. The AIMD may also be required to modify the compressor rotor or stator blades as a result of a technical change or bulletin. Modifications may include reworking the components, changing by stages, or replacing the entire rotor assembly.

Compressor Blades

Damaged compressor blades can be reworked not to exceed the damage limits as specified in the applicable technical instructions. It is not feasible to describe all of the damage conditions that might occur. If you have a reasonable doubt as to the strength of the reworked blade, even though it may be within the prescribed limits, reject the compressor rotor. Nicks and dents in the leading and trailing edges in the upper two-thirds of the blade airfoil may be reworked by filing or grinding. Then it receives a final polishing to form a smooth blend with the basic airfoil contour. Removal of material to eliminate the damage should always be held to a minimum. The final polishing of the reworked area of the blade must be in a longitudinal direction on the blade airfoil with a 40-microinch finish or better. No sharp edges, burrs, cracks, or tears in the blade surface are allowed after the rework. The blade dimensions must remain basically unchanged in the lower one-third of the blade airfoil. You should rework all minor nicks, scratches, or abrasions in the leading and trailing edges that can be reworked

by light polishing only. Damage limits are shown in figure 3-1.

Straightening the blade to remove dents is only allowed in the upper one-third of the airfoil, provided the damage does not exceed the limits shown in figure 3-2. The tools used to straighten the blade must have a smooth surface to avoid additional damage to the blade surface. Compressor blade tip damage may be re-formed by straightening or reworking within the limits as shown in figure 3-3. Blades with minor surface damage in the upper two-thirds of the airfoil, other than in the leading and trailing edge areas, can be reworked within the limits shown in figure 3-4. Rework should consist of nothing more than blending out the sharp edges. After rework, all blades must be inspected for cracks using dye penetrant inspection procedures.

NOTE: Compressor cases are machined in matched sets. Damage beyond repair to one case is cause for rejection of the opposite case. A new compressor rotor is not required when replacement of the entire case assembly is necessary.

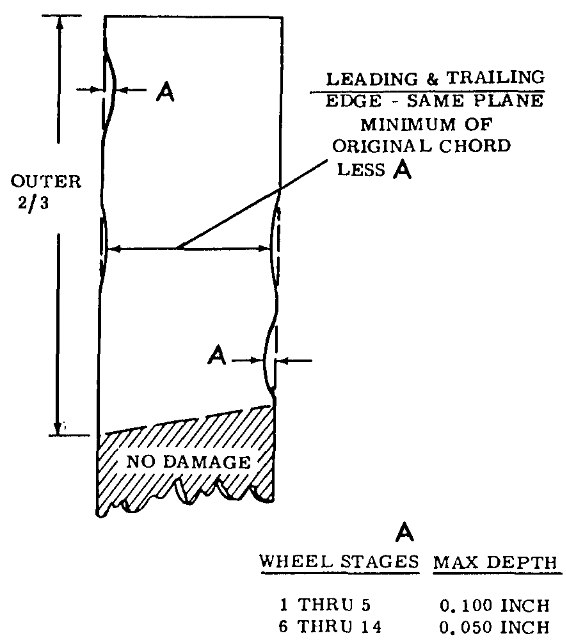


Figure 3-1.—Compressor blade leading and trailing edge damage limits.

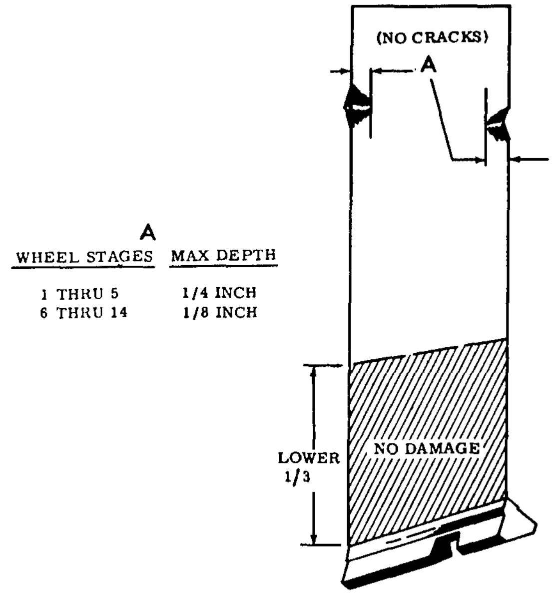


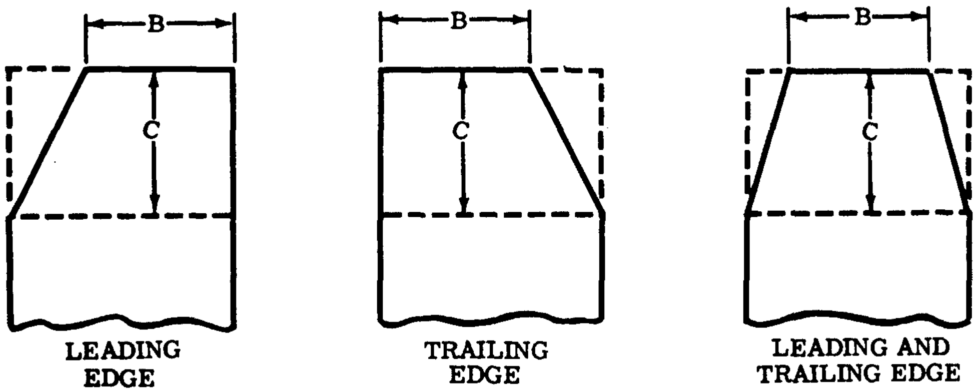
Figure 3-2.—Compressor blade dent damage limits.

The compressor blade corrosion limits are given in figure 3-5.

Compressor Vane Assemblies

Repair to the compressor vanes is limited to straightening the leading and trailing edges of the vane. This is permitted within the areas of the vane length as shown in figure 3-6, providing the displaced material does not exceed 3/32-inch distance toward either side of the vane. Straightening of folded or rolled back edges is not permissible. If this type of damage can be removed within acceptable blending limits, the vane is acceptable and may be retained in service. Nicks and tears are not acceptable and must be removed within acceptable blending limits. After straightening, waves or bumps must not exceed a depth of 1/64 inch (as measured from peak to valley in a radial plane) across the vane. The vane should be of the same original contour, and this can be determined by both sight and feel.

Blending is permitted in the areas of the vane length and depth, as shown in figure 3-6, to remove nicks, folds, kinks, and tears. Before blending compressor vanes that have been straightened, you should inspect the straightened



	B	C
Stage	*Minimum Blade Tip*	*Total Airfoil Rework Length*
1	49/64	1/5
2 thru 5	51/64	1/5
6 thru 14	3/8	1/5

Figure 3-3.—Compressor blade tip damage and rework limits.

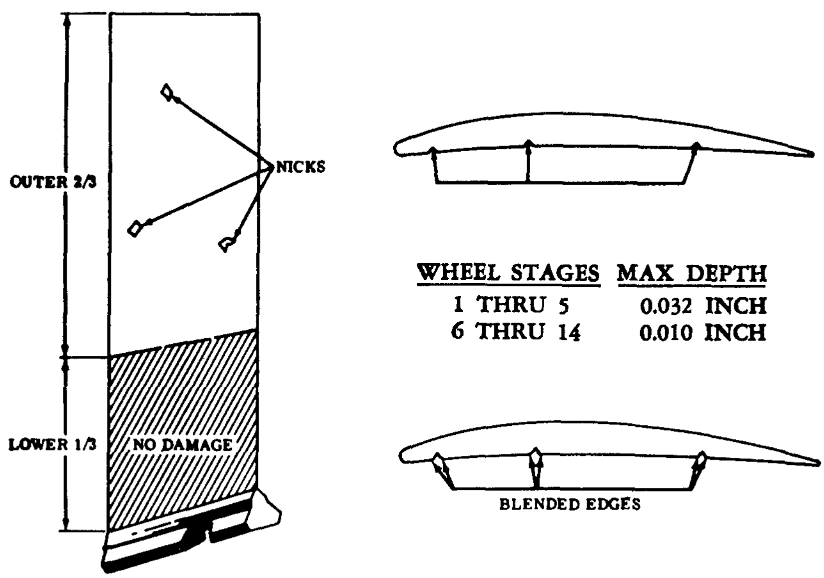
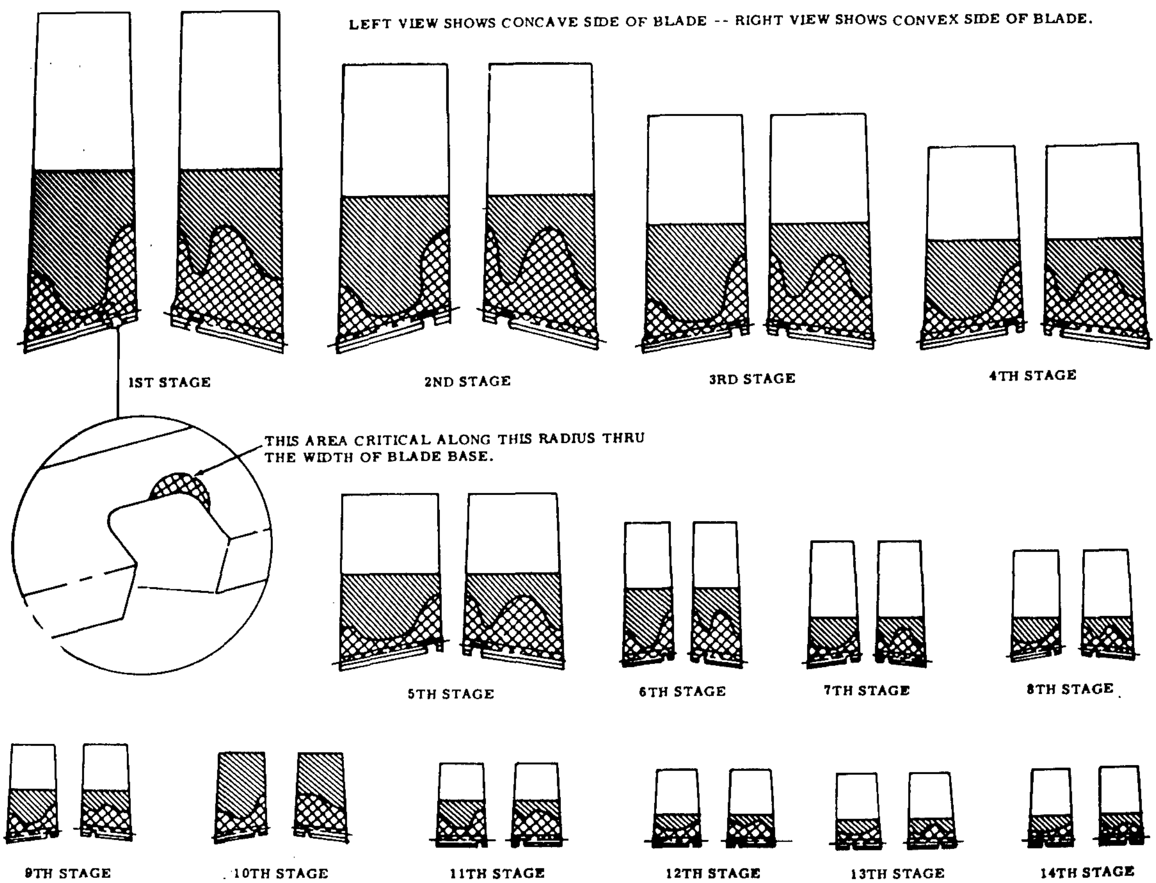


Figure 3-4.—Compressor blade surface damage limits.



CRITICAL AREA

a. *Slight pitting* (No. 1) is acceptable. Pit depth must not exceed 0.004 inch.

b. *Pitting clusters* (No. 2) are not acceptable in this area.

SEMI-CRITICAL AREA

a. *Scattered pitting* (No. 3) is acceptable, provided the pits do not form a definite line across the blade width.

b. *Pitting clusters* (No. 2) are not acceptable in this area.

NON-CRITICAL AREA

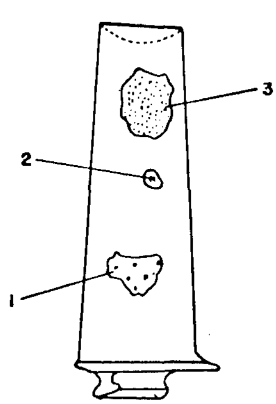
a. *Scattered pitting* (No. 3) is acceptable, provided the pits do not form a definite line across the blade width.

b. *Pitting clusters* (No. 2) are acceptable if not exceeding:

(1) Stages 1-5: Two pitting clusters per side and depth does not exceed 0.010 inch.

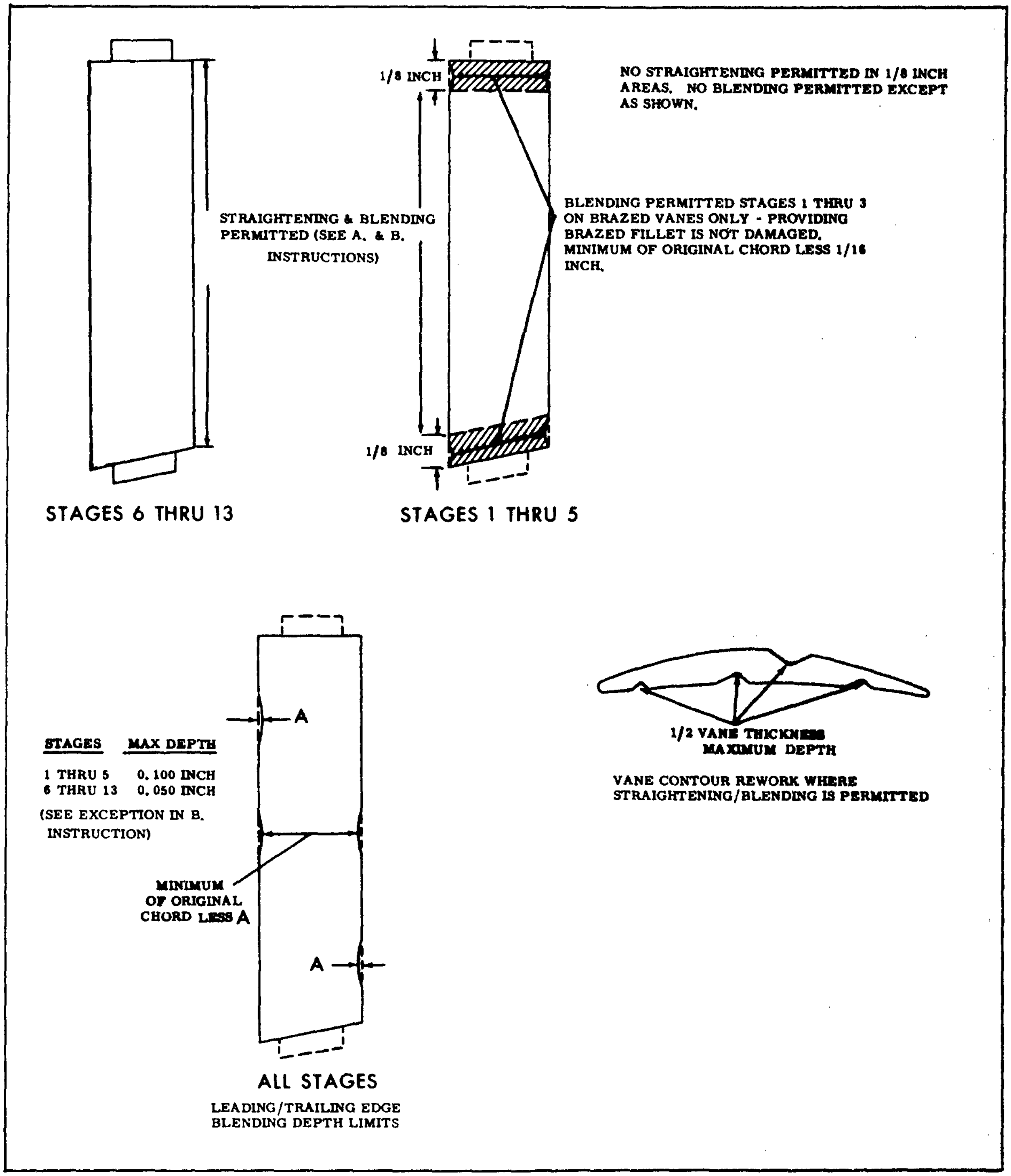
(2) Stages 6-14: One pitting cluster per side and depth does not exceed 0.005 inch.

c. *Pitting clusters* (No. 2) are only acceptable in the center ⅓ of blade width and they must not oppose each other from opposite sides.



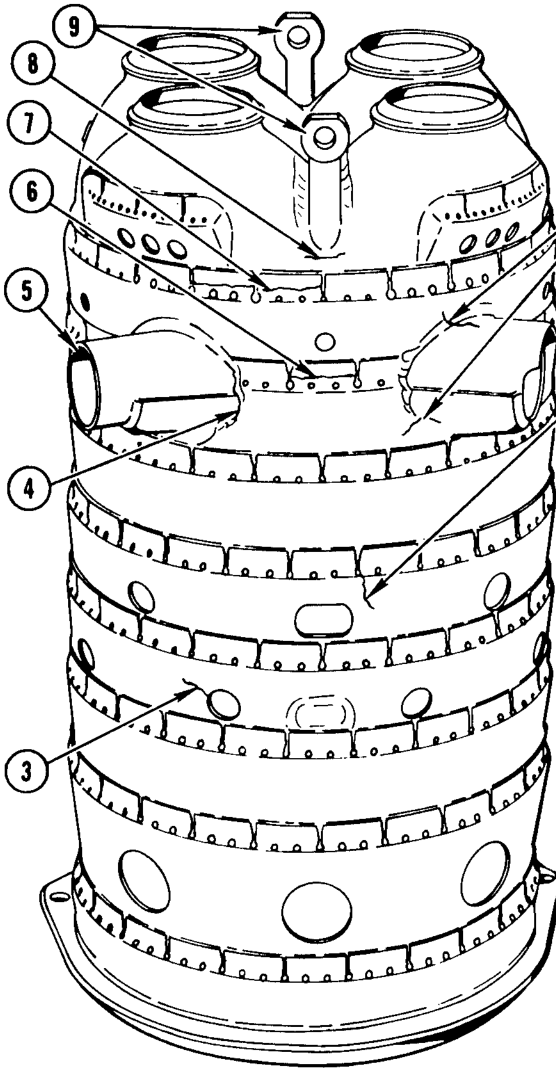
PITTING EXAMPLES

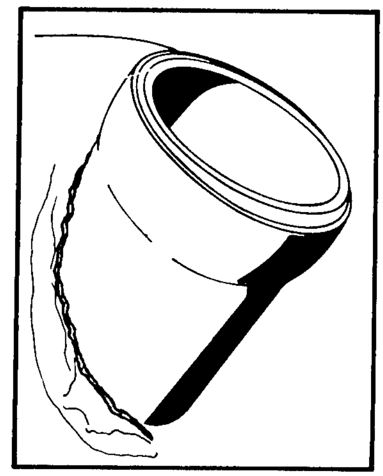
Figure 3-5.—Compressor blade corrosion limits.



204.109

Figure 3-6.—Compressor vane rework limits.





TYPICAL IGNITER SLEEVE
DETAIL SHOWING CRACK AT WELD

1. Minor cracking or buckling is serviceable.
2. Cracks visible on OD must be weld-repaired; minor cracks visible on ID of cooling air louver lip are serviceable.
3. Minor cracks 0.125 inch or less long are serviceable if not more than three in number per segment.
4. Minor cracks 0.060 inch or less long are serviceable.
5. Burned or warped areas are not serviceable.
6. Typical 2nd louver crack; not serviceable without weld-repair.
7. Typical 1st louver crack; not serviceable without weld-repair. Reparable limits: single crack maximum length three inches: maximum of four cracks around circumference with maximum six-inch cumulative length.
8. Crack in weld at base of mount lug is not serviceable without repair. Lug pinhole axis alignment must be maintained.
9. Mount lug radial or circumferential cracks are not serviceable without repair.

204.27

Figure 3-7.—Combustion chamber liner limits.

portion of the vane for evidence of previous folds, kinks, or rolled edges. If these types of defects cannot be eliminated by metal removal within acceptable blending limits, the compressor section should be replaced. Blending may be accomplished by grinding or filing, and then a final polishing to form a smooth blend with the basic airfoil contour. All the vane blending should be done in a longitudinal direction (lengthwise of the vane) with a 40-microinch finish or better. As with the compressor blades, a minimum amount of material should be removed to correct any defect. Repair to the vane contour is limited to straightening in the areas of the vane length as shown in figure 3-6, and blending should be accomplished (to a prescribed limit) in the same manner as the leading and trailing edge blending.

COMBUSTION SECTION

The combustion section can be removed, repaired, or replaced in part or entirely depending on the extent of damage encountered. The combustion section consists of liners, outer case, transition duct, inner case, and the first stage turbine nozzle assembly. Most repairs to this section are accomplished by welding or replacement of components.

Combustion Chamber Liners

Inspect combustion chamber liners for cracks by visual inspection and dye or fluorescent penetrant inspection procedures. Cracks converging in such a manner that metal could subsequently break loose, and any cracked or damaged swirl vanes are cause for rejection of the liner. Liners having buckled areas in a weld seam or areas in excess of a 3/16-inch wave, that do not include the weld seam, must be removed from service.

Combustion chamber liners may be retained in service when the following conditions are met: cracks less than 0.125 inch long emanating from the combustion air hole (no more than three per section) and radial or circumferential cracks less than 0.750 inch long extending from or around the crossover tubes or igniter plug bosses. The reuse of combustion liners that show evidence of burning is permitted. Cracked deflectors must be reworked to remove cracked areas by blending or cutting prior to reuse. Burning of the cooling louver must not exceed two tabs totally burned or a total area of two tabs per liner. (See figure 3-7.) The repair and/or rejection criteria for the combustion liner will vary with each particular engine.

Combustion Chamber Support

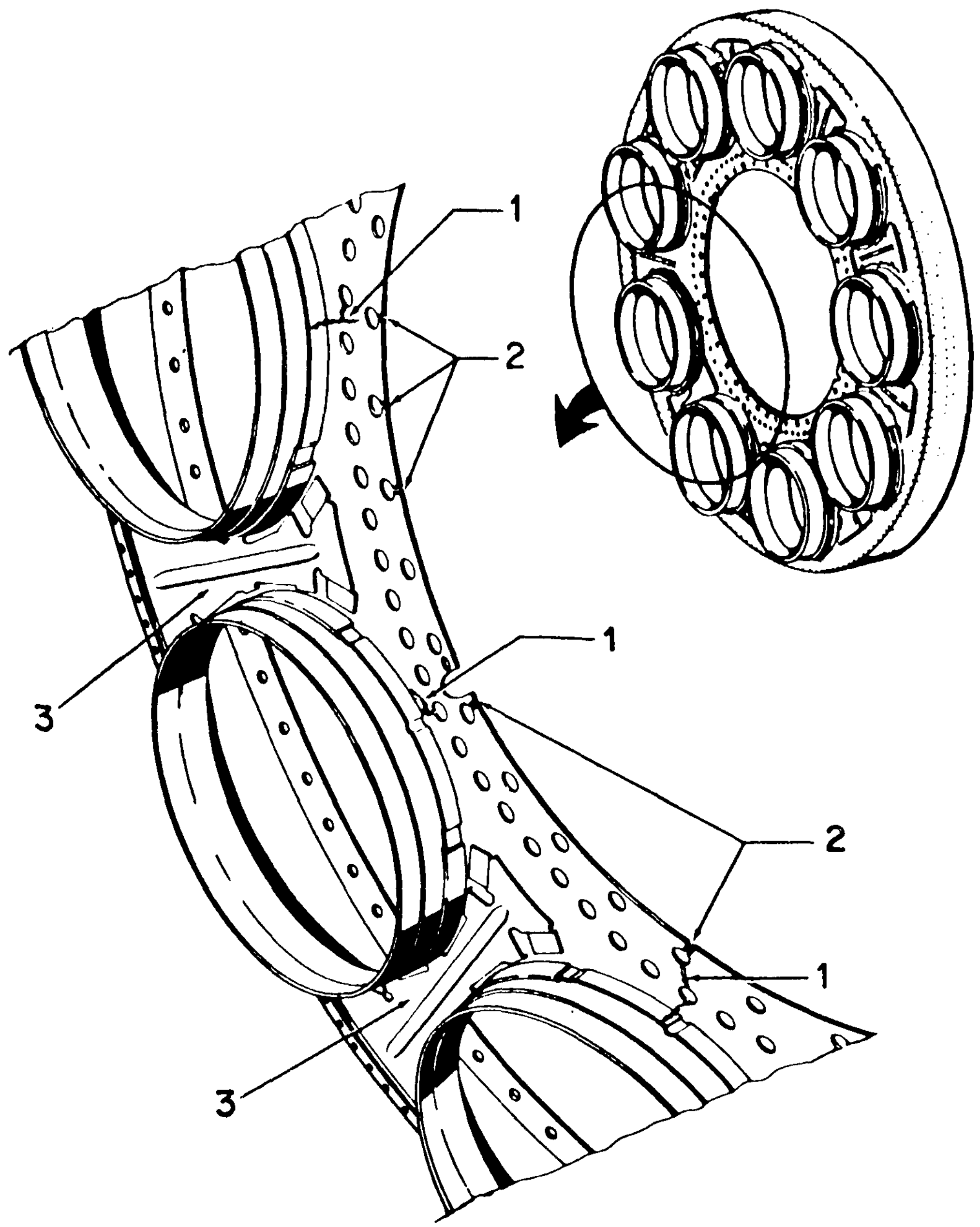
Cracks in the combustion chamber support can be repaired by inert-gas fusion welding. Repairs must not result in distortion or misfit of parts at assembly. If a hole is distorted as a result of welding, use a file to restore it to its original configuration. The weld bead must be blended by hand after the welding. (See figure 3-8.)

Combustion Chamber Inner and Outer Outlet Ducts

Operational cracks in the inner and outer outlet ducts up to 3 inches in length may be allowed to remain in service, provided there are no more than two cracks per duct. Cracks in excess of 3 inches and exceeding 75 percent of the entire circumference of the duct at the station must be repaired by gas fusion welding. When you repair a duct, use a silicone carbide grinding wheel, grinding a 90-degree Vee groove, 0.035-inch deep, for the entire length of the crack. Repairs must not result in distortion or misfit of the parts at assembly. File out any hole that is distorted as a result of welding to restore it to its original configuration. (See figure 3-9 for inner and outer outlet ducts limits.)

TURBINE SECTION/TURBINE BLADES

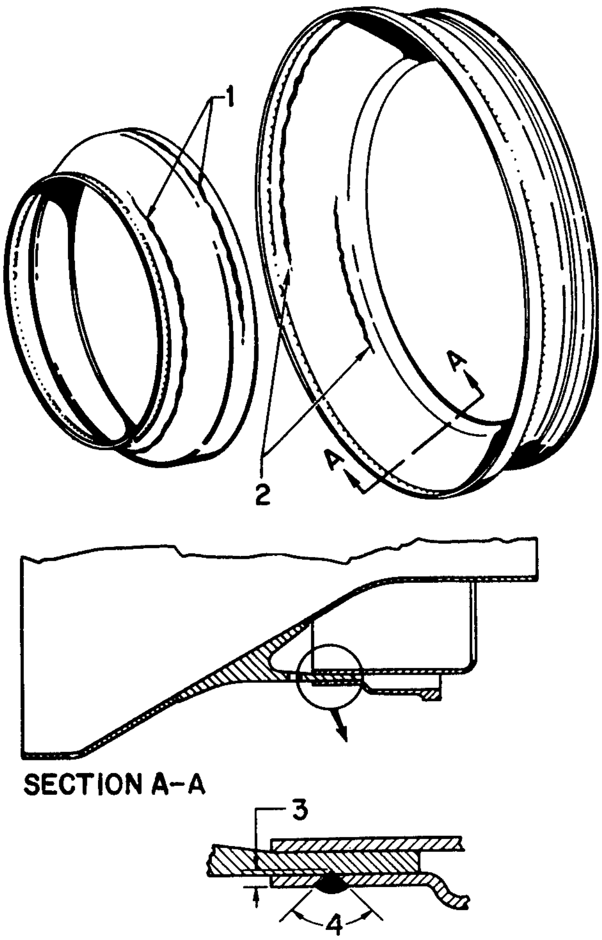
Because of the extreme heat encountered in the turbine section, careful inspections must be accomplished. Turbine sections can be replaced in whole or in part. The turbine rotor is usually repaired by changing individual blades or an individual rotor. It is not feasible to describe all of the damage conditions that may be found in the turbine. If the damage is within prescribed limits, but there is still reasonable doubt as to the reworked blade strength as compared to a new blade, you should replace the turbine rotor.



1. Maximum length of crack 2 inches.
2. Cracks, maximum of 33 percent and not more than three adjacent holes.
3. Only one crack per section permitted and it must be welded.

204.28

Figure 3-8.—Combustion chamber support limits.



1. Cracks, inner duct.
2. Cracks, outer duct.
3. 0.035 inch.
4. 90 degrees.

204.29

Figure 3-9.—Combustion chamber inner and outer outlet ducts.

First stage turbine blades are coated with a protective coating to prevent sulfidation. Alpak is normally used for coating these blades. Without this coating, these blades are very susceptible to sulfidation. Normally, when minor nicks or dents are found on these blades, the damage would be blended and/or polished to leave a smooth finish. Minor nicks or dents in the 1st- and 2nd-stage turbine blades are acceptable if they are less than 1/64-inch deep. Any damage beyond this limit is cause for rotor replacement.

All blades should be inspected for sulfidation. This form of corrosion is permissible if evidenced only by a rough or crusty appearance at the leading edge, on the concave side of the airfoil section, or on the platform at the root of the airfoil. The rotor should be replaced if there is evidence of splitting, delamination, separating, flaking, or loss of material in any area of the blade. Figure 3-10 shows an example of unacceptable sulfidation of turbine blades.

The 3rd- and 4th-stage turbine blades are not coated with a protective coating, and it is permissible to rework these blades according to the limits shown in figures 3-11 and 3-12. Blades with damaged airfoils, other than in the leading or trailing edge, may be reworked by blending burrs and sharp edges not to exceed one-half the airfoil thickness or 1/64 of an inch, whichever is smaller. Dye check all reworked blades for cracks.

EXHAUST SECTION

The exhaust section can be as simple as a single duct, or, if the engine is equipped with an afterburner, have several parts or assemblies. This section requires careful inspection because of the extreme heat conditions encountered. Welding is one of the primary repair methods used on this section.

MAIN ENGINE BEARINGS

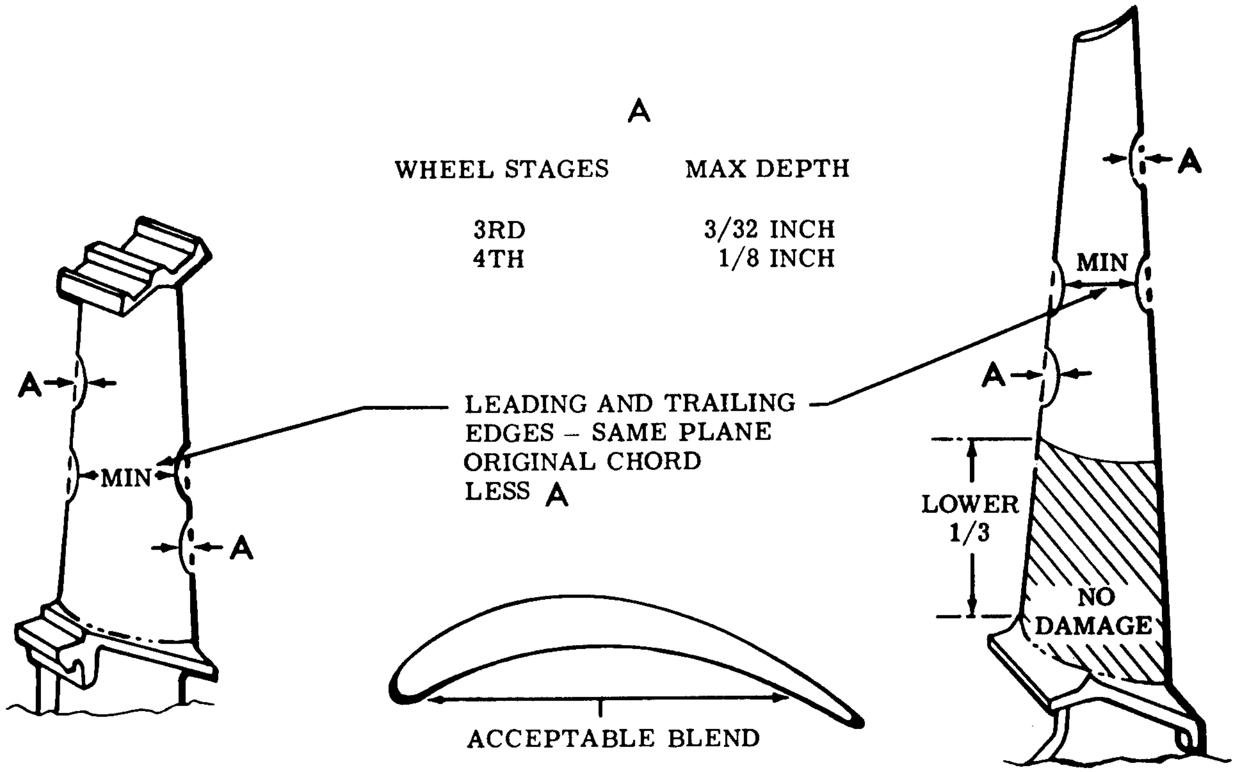
The number of main engine bearings may differ from one model engine to another. With the engine disassembled and in the vertical position, all bearings and housings can be inspected and replaced as necessary. Because of the high RPM, this is one of the more critical sections of an engine.

ACCESSORIES DRIVE SECTION/GEAR INSPECTIONS

The accessories drive section contains the various gearboxes for driving the accessories. These gearboxes should be inspected for cracks and worn areas, and the splines should be checked for proper fit and clearances. When you remove or replace the gearboxes from the engine,

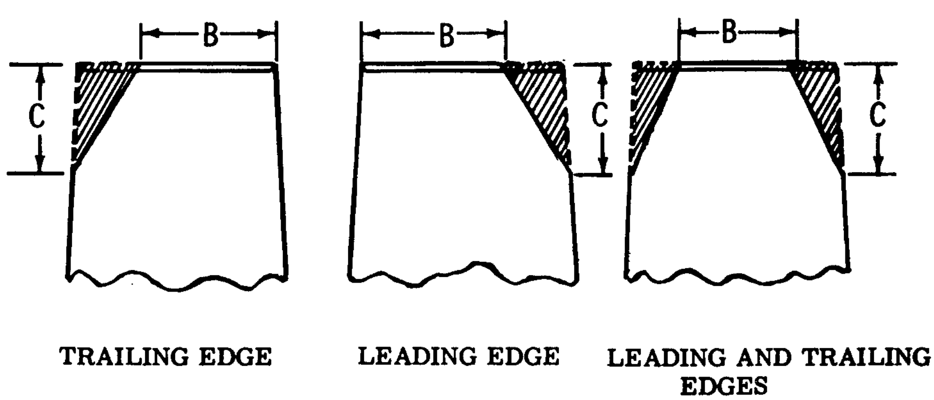
204.110

Figure 3-10.—Examples of unacceptable sulfidation of turbine blades and vanes.



204.111

Figure 3-11.—Turbine blade rework limits.



The rework area shall conform to a straight line from the edge to the tip, such that a minimum of material is removed and the damage completely included.

Stage	*Condition*	*After Rework*
4	B	¾
	C	¾

204.112

Figure 3-12.—Turbine 4th-stage blade tip rework limits.

the splined drive shafts that are connected to the engine rotor shafts must be carefully removed or installed to prevent spline damage.

Most mating gears require backlash as well as end clearance checks. You should carefully inspect the gear and spline teeth for irregular or excessive wear, galling, and flaking. Usually, runout measurements are not required if there is no evidence of gear teeth spalling. These checks may require partial assembly of the parts and will be accomplished during assembly of the components.

CHAPTER 4

PROPELLER MAINTENANCE

In today's modern and complex Navy, comprehensive and systematic means of maintaining a multiengine propeller system is essential. You, as the chief or first class Aviation Machinist's Mate supervisor, are required to know the procedures for day-to-day maintenance, troubleshooting, removal and installation of a propeller, rigging and adjustment, and a knowledge of correcting propeller system malfunctions. In addition to the regular maintenance and servicing requirements for a propeller system, you must know the procedures for propeller buildup (including balancing and leakage test requirements).

The purpose of this chapter is to provide a generalized picture and description of a propeller assembly and some common troubleshooting procedures for a constant speed variable pitch propeller system. We will also discuss propeller buildup, balancing requirements, and external and internal hydraulic leakage test requirements.

There are a variety of turboprop aircraft being used in the Navy today. The C-130 Hercules cargo transport aircraft, (figure 4-1, view A), the workhorse of naval aviation, uses the 54H60-111 model propeller. The E-2 Hawkeye (figure 4-1, view B), the fleet's airborne early warning aircraft, and the C-2 Greyhound (figure 4-1, view C), a fleet logistics support aircraft, both use the 54H60-1 model propeller. The P-3 Orion (figure 4-1, view D) is our fleet ASW aircraft, and it uses the 54H60-77 model propeller. In this chapter, the 54H60-77 model propeller is the example of a common propeller system we will be discussing. There are differences in the propeller systems mentioned above; but the basic assemblies, maintenance, buildup, and troubleshooting will be similar on all propeller systems.

When you are performing maintenance, or actual troubleshooting, always refer to the appropriate technical publication for the model propeller on which you are working.

PROPELLER SYSTEM

The complete 54H60-77 model propeller, shown in figure 4-2, consists of the front anti-icing propeller spinner, the hub mounting bulkhead assembly, the variable pitch aircraft propeller (propeller assembly), the rear deicing propeller spinner, the air baffle assembly, the integral oil control assembly, and the propeller afterbody assembly. At approximately Mach 1 speed, the turboprop engine can deliver more thrust than the turbojet engine of the same gas turbine design. For a given amount of thrust, the turboprop engine requires a smaller gas turbine with lower fuel consumption than the turbojet engine.

The propeller system has one primary function—increasing or decreasing pitch as required by power lever movement. Safety features incorporated in the 54H60-77 propeller system include the automatic mechanical pitchlock, the automatic negative torque control, the mechanical low pitch stop with a secondary hydraulic low pitch stop (referred to as the Beta follow-up), and an emergency feathering system. The modern-day propeller system is a complex and durable system and, with proper maintenance, a highly reliable aircraft system.

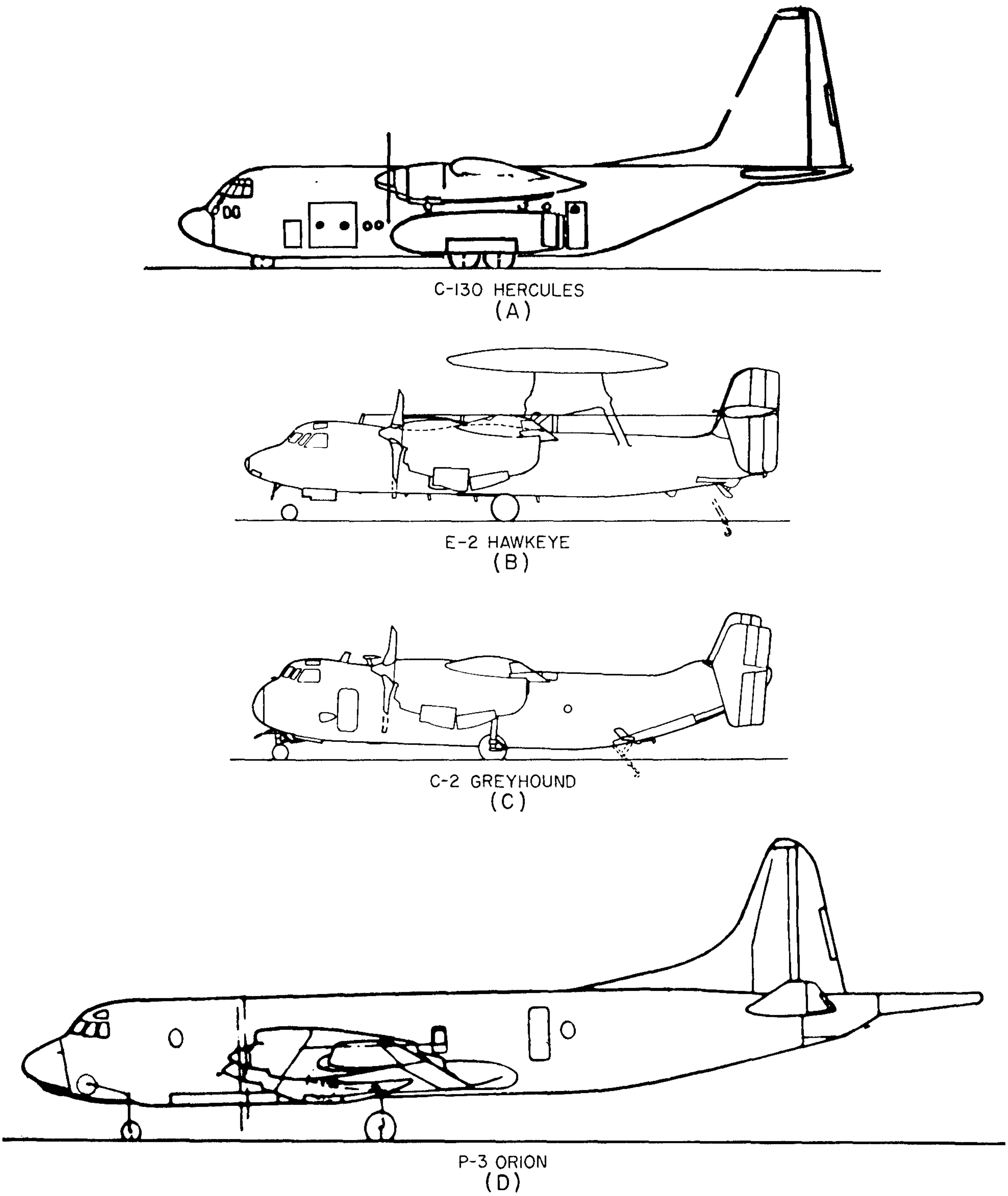


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Figure 4-1.—Four turboprop aircraft.

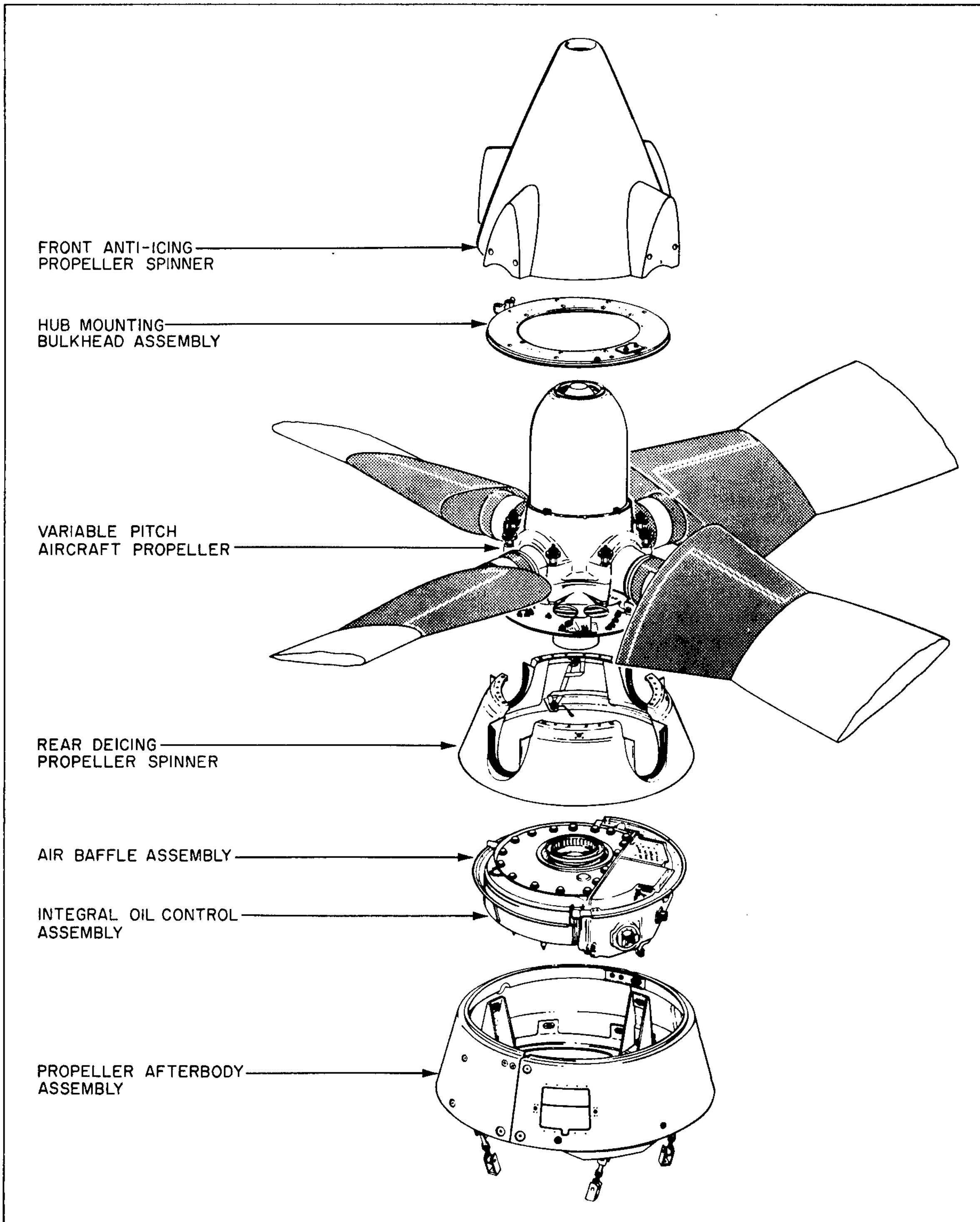

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Figure 4-2.—Propeller system.

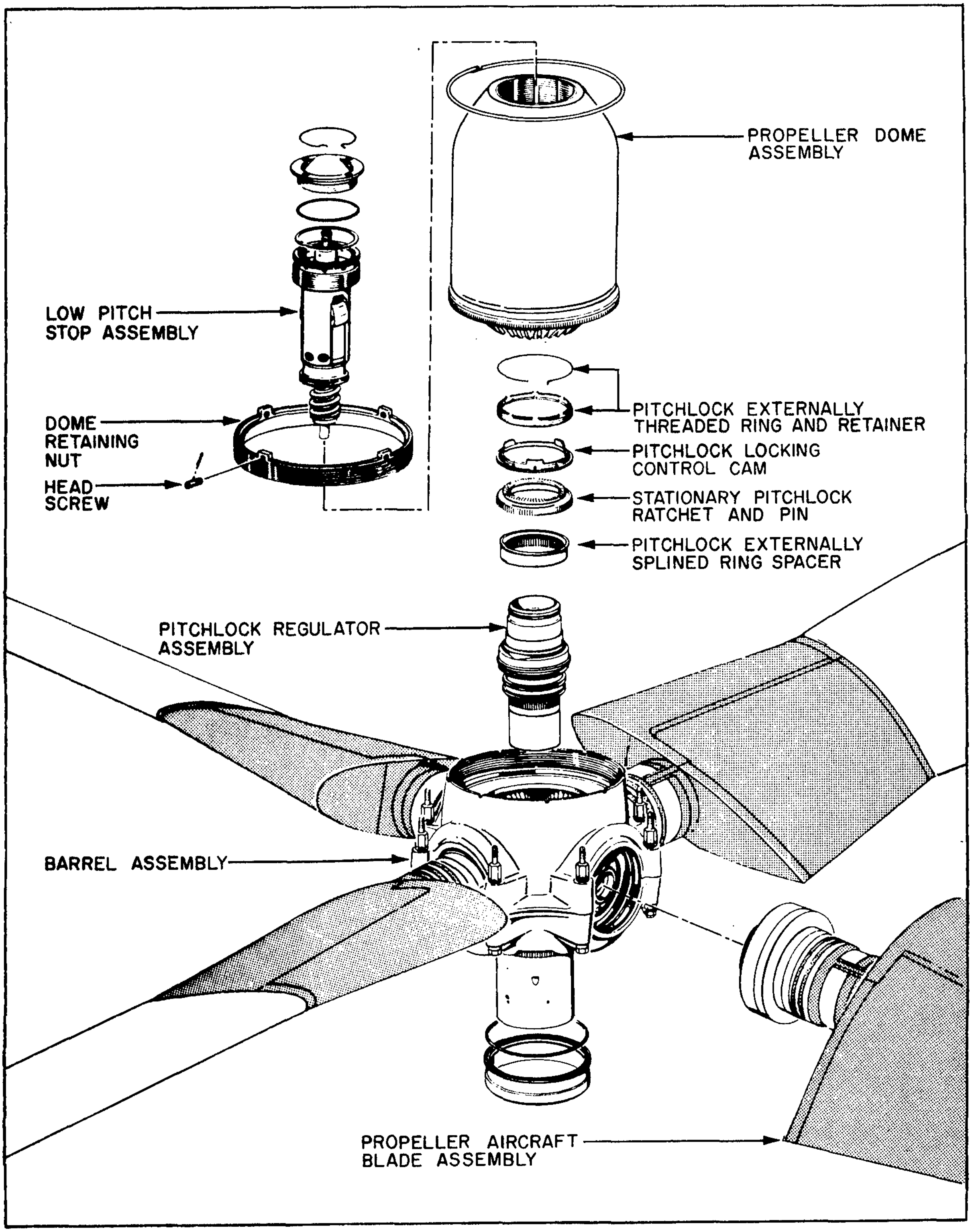

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Figure 4-3.—Variable pitch aircraft propeller.

PROPELLER ASSEMBLY

The variable pitch aircraft propeller (propeller assembly) is shown in figure 4-3. The propeller assembly has five major subassemblies—the barrel assembly, the propeller blade assembly, the propeller dome assembly, the low pitch stop assembly, and the pitchlock regulator assembly.

The propeller blades are 13.5 feet in diameter and have an operating range of approximately 101 degrees of blade travel with a reverse blade angle setting of a minus 14.5 degrees. The low pitch stop assembly is set at a plus 13 degrees and the feather blade angle is set at a plus 86.65 degrees.

The propeller maintains a constant RPM of 100 percent of the engine speed at any condition above flight idle. This range of operation is called the alpha range. The alpha range is from flight idle to takeoff. The beta range is used for ground handling, taxiing and reverse operation. The beta range is from the flight idle blade angle to the full reverse blade angle. The propeller blades in the beta range of operation can provide zero thrust at the ground idle position and negative thrust in the reverse position.

The propeller assembly has the capability of handling in excess of 4,000 shaft horsepower generated by the turbine engine. It also has the ability to handle any rapid power changes that may be encountered.

Barrel Assembly

The propeller barrel assembly (figure 4-4) serves several functions. It retains the four propeller blades and also supports the dome assembly and the propeller control assembly. Engine torque is transmitted to the propeller by the barrel assembly, which is mounted and secured to the front of the reduction gearbox propeller shaft.

As we discuss the barrel assembly, refer to figure 4-4 for nomenclature identification. The barrel assembly is a split type; the front and rear barrel sections are manufactured and balanced as a matched pair. These sections are kept together throughout the service life of the propeller. The high centrifugal blade loads are carried by the barrel shoulders and lips at each blade position.

A machined integral extension on the rear barrel half is splined internally and has seats at both ends. The front and rear cones are beveled to match the extension seats for centering and securing the propeller on the propeller shaft. The extension is splined externally for driving pumps in the propeller control assembly. A propeller hub nut locks the barrel assembly to the reduction gearbox propeller shaft. The propeller hub nut has a flange on its inboard end which butts against the front cone.

Eight internally relieved stud extensions (internally drilled to measure bolt elongation) are installed on the threaded ends of the special relieved bolts (barrel bolts) to provide attachment points for the hub-mounted bulkhead assembly. The front spinner assembly is, in turn, mounted to the hub-mounted bulkhead assembly.

Blade Assembly

The basic propeller blade assembly (figure 4-5) consists of a propeller blade, split roller thrust bearing, split thrust washer, blade seal preformed packing and packing lock ring, segment blade gear, blade microadjustment ring, and blade barrel shim. The number 1 blade has the beta segment gear; the remaining blades have a spider shim plate. The blades are sealed within the two barrel halves by the blade seal preformed packings, which fit inboard of the lip of the barrel halves. The blade seal preformed packings are prevented from rotating by the packing lock rings. The lock rings have two pins that extend into grooves in the barrel, locking the packings and packing lock rings in place.

The broad, lightweight propeller blade is forged from a solid aluminum alloy, which gives it the strength necessary to obtain the high thrust capability at low aircraft speeds. The blade butt is partially hollow to allow for installation of the blade bushing and blade balancing assembly. Propeller balancing is discussed in the balancing section of this chapter.

The blade shank has a molded fairing that is composed of a plastic foam material covered with a nylon reinforced neoprene material. The heater assembly is bonded to the leading edge of the fairing. It contains the necessary blade deicer elements to prevent ice buildup on the blade assembly. Blade heater element damage, involving cut or broken heater wires because of weather corrosion or FOD strikes, can be

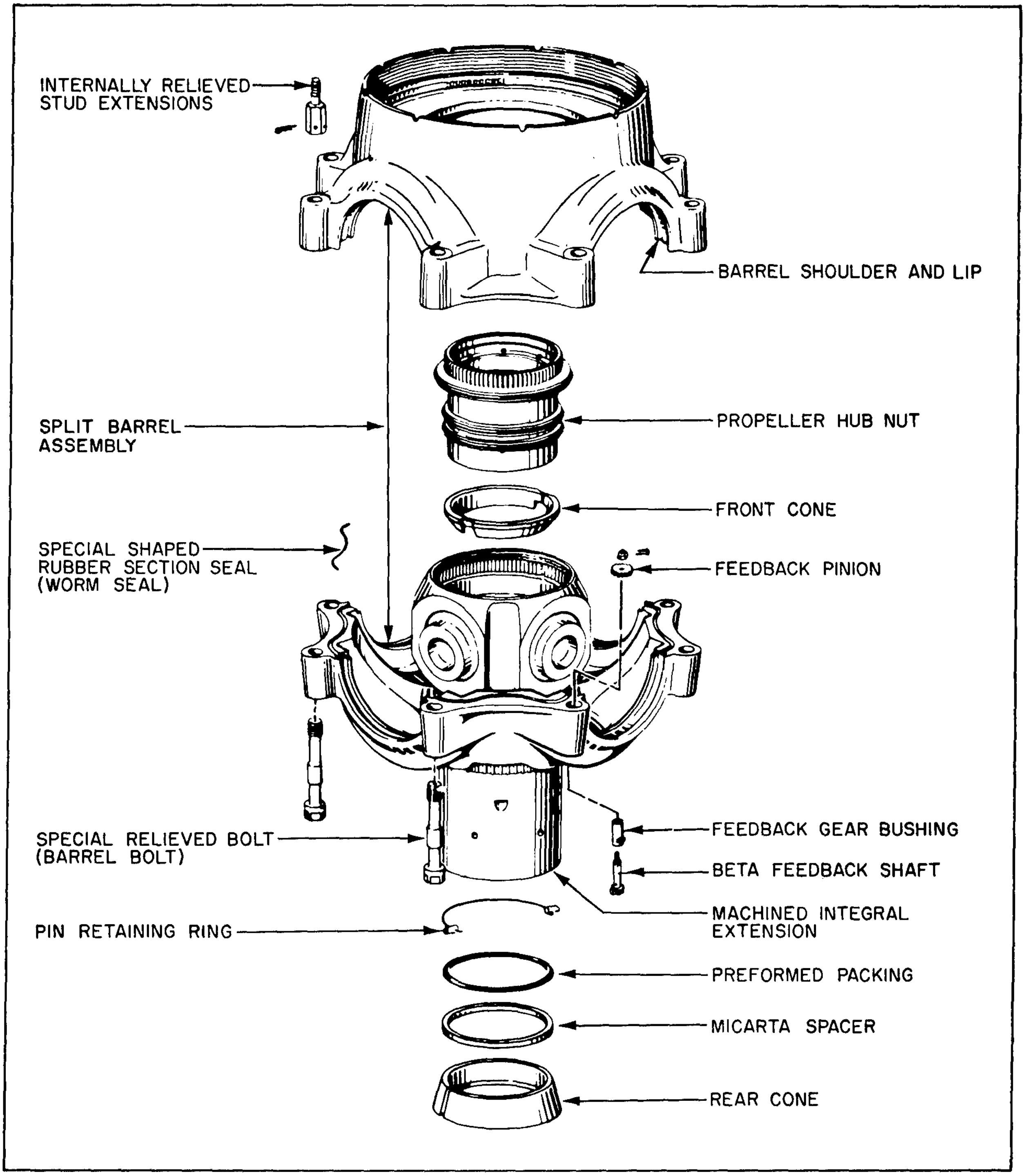

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Figure 4-4.—Propeller barrel assembly.

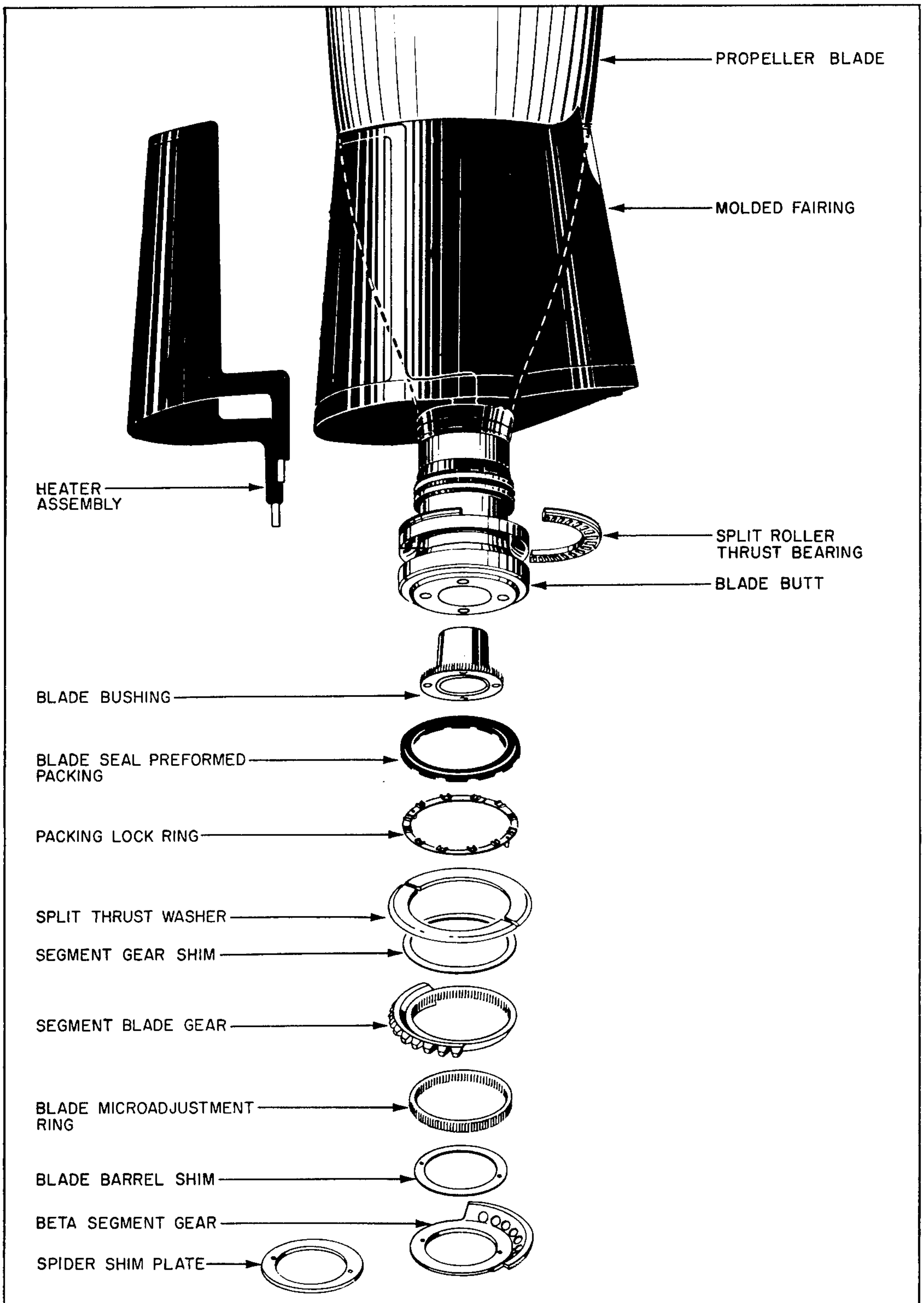

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Figure 4-5.—Propeller blade assembly.

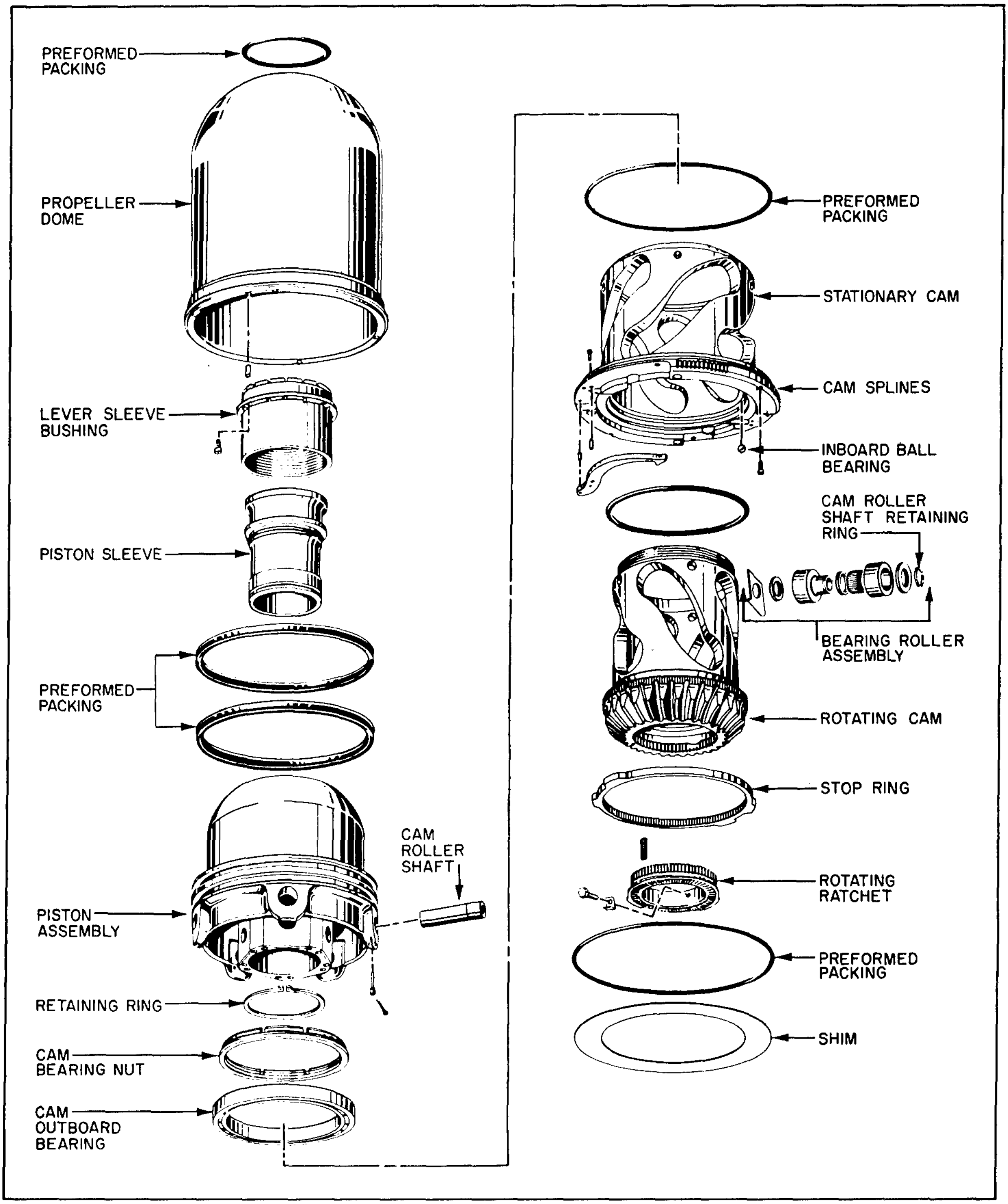

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Figure 4-6.—Propeller dome assembly.

repaired if no more than four wires are damaged. If more than four wires are damaged, the heater assembly must be replaced. The purpose of the blade fairing (cuff) is to streamline and direct the airflow to the engine intake.

Dome Assembly

The propeller dome assembly (figure 4-6) is the blade angle changing mechanism of the propeller system. The dome assembly is mounted on the front barrel shelf and held in position by the dome retaining nut. (See figure 4-3.) The principal components of this pitch-changing mechanism are the rotating cam, the stationary cam, the piston assembly, and the low pitch stop assembly. The low pitch stop assembly is screwed into the lever sleeve bushing at the front of the dome.

The rotating cam and the stationary cam are assembled as one unit by the use of inboard ball bearings and a bearing retaining nut that allows the rotating cam to turn freely within the stationary cam. The stationary cam is held in a fixed position on the front barrel shelf with cam splines that engage the splines on the inside wall of the barrel. The cam outboard bearing is a single unit, but the inboard ball bearings consist of 65 loose steel balls that are installed by hand at the time of assembly. The inner race is installed on the rotating cam and the outer race is installed on the stationary cam. The stationary cam has five slotted cam tracks that oppose the five slotted cam tracks, on the rotating cam. A bearing roller assembly is mounted on a cam roller shaft that travels in the tracks of both cam slots. The cam roller shafts are fixed in the walls of the piston assembly. The inboard or outboard motion of the piston results in the cam rollers acting on the cam tracks, causing the rotating cam to turn. Gear teeth on the end of the rotating cam mesh with the teeth of the segment blade gear. (See figure 4-5.) Movement of the segment blade gear, which is connected to the blade butt, causes blade rotation.

The piston assembly is a double-walled aluminum casting that fits over the stationary and rotating cams, and it is secured in position by the cam roller shafts. The shafts are press fit into holes through the piston walls and locked in place by the cam roller shaft retaining rings. A piston sleeve is fit into the piston to provide a sliding sealing surface between the piston and the low pitch stop lever assembly. (See figure 4-6.) This sleeve contacts the stop lugs on the lever arms of the low pitch stop lever assembly when the piston sleeve is at the low blade angle.

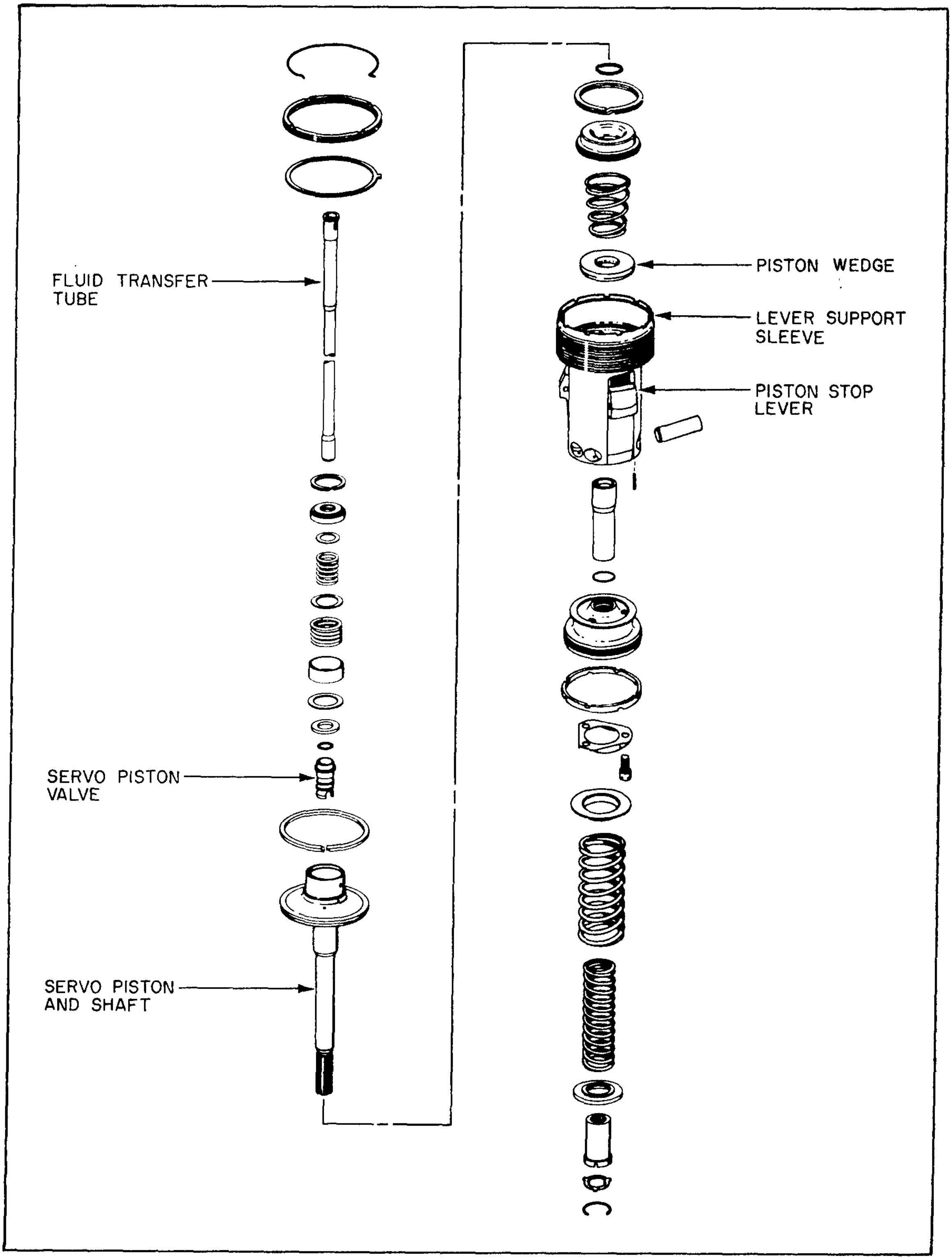
Preformed packings are used throughout the dome assembly for internal leakage control and to seal the piston assembly in order to separate the inboard and outboard hydraulic pressure necessary for blade movement. Shims are used to establish the proper clearance between the rotating cam and the blade segment gears. The dome assembly is mounted in position on the front barrel shelf and held in place by the dome retaining nut that is locked in place by a special head screw.

NOTE: When you are installing the dome assembly, make sure that shims of the same thickness are used. The thickness size is normally acid etched on the barrel shelf.

Low Pitch Stop Assembly

The low pitch stop assembly (figure 4-7) has external threads, and it is mounted to the dome assembly by screwing the stop assembly into the dome lever sleeve bushing (figure 4-6) to set the desired low pitch stop blade angle. The application of extra high inboard hydraulic fluid pressure actuates the low pitch stop assembly mechanism. The mechanism moves the three stop levers from the piston lever sleeve's path, thus allowing the piston to move further outboard. This turns the blades from the low pitch stop position towards the reverse blade angle. This higher hydraulic fluid pressure flows between the outside diameter of the fluid transfer tube and the inside diameter of the servo piston and shaft. A servo piston valve opens at a predetermined pressure allowing pressurized fluid to move the servo piston and shaft.

When the servo piston and shaft move, it causes the piston wedge to move. This allows the piston stop levers to collapse inward. The dome piston is thus permitted to move forward from the low pitch stop setting moving the blades toward reverse. An orifice, incorporated in the servo piston and shaft, is used to bleed entrapped air with the returned fluid into the atmospheric sump of the pump housing assembly.



204.117

Figure 4-7.—Low pitch stop assembly.

In the flight range of operation, the low pitch stop lever assembly prevents the propeller blade angle from going below 13 degrees.

Pitchlock Regulator Assembly

The propeller pitchlock regulator assembly (figure 4-8) is mounted within the propeller barrel and splined into the propeller hub nut. (See figure 4-4.) The main components of the pitchlock regulator assembly are the pressure regulating/pressurizing valve, selector valve, servo valve, flyweights, pitchlock speed reset actuating valve, and the speed reset bias plunger.

The regulator assembly is secured in position by an externally splined ring spacer, stationary pitchlock ratchet and pin, and a locking control cam that is locked in place by an externally threaded ring and its retaining ring. (See figure 4-3.) The pitchlock ratchet ring must be carefully aligned as specified in the appropriate technical publication.

The purpose of the pitchlock regulator assembly, in addition to directing hydraulic pressure to the outboard and inboard sides of the dome piston, is to prevent a decrease in blade angle if hydraulic control pressure is lost or an overspeed of 103 to 103.5 percent occurs. The pitchlock regulator assembly contains two ratchet rings that are spring-loaded together, but are held apart by hydraulic pressure.

One ratchet ring is splined to the rotating cam of the dome assembly; the other ratchet ring is splined to the propeller rear barrel half and does not rotate. If hydraulic pressure is lost, the ratchet rings come together and their teeth mesh to prevent a decreased blade angle. This is referred to as pitchlock and can only occur between approximately 15 to 60 degrees of blade angle.

The pitchlock regulator assembly also contains flyweights that keep the servo valve closed to prevent loss of hydraulic pressure. If the engine speed exceeds 103 to 103.5 percent, the flyweights move outward to open the servo valve and relieve any pitch change or residual hydraulic pressure. This interaction causes the spring-loaded ratchets to mesh together to prevent a blade angle decrease. The propeller is then operated as a fixed-pitch propeller. However, the reverse rake of the pitchlock ratchet teeth allows rotating of the propeller into higher blade angles, at all times, for feathering or to regain control of the propeller.

To prevent pitchlock engagement during landings and aborted takeoffs, the pitchlock ratchets are held disengaged by a higher internal hydraulic pressure. This condition occurs through the actions of the pitchlock reset solenoid valve and pitchlock reset regulator valve located in the pump housing assembly. Residual pitch change hydraulic pressure in the pitchlock regulator keeps the ratchet rings separated. This separation is temporary when pitch change pressure is not required in flight and during intermittent decrease pitch operation statically on the ground. Pitchlock cannot occur below a blade angle of approximately 14.5 to 17 degrees and above approximately 57 to 60 degrees. Pitchlock does not occur because it is cammed-out mechanically through the action of the pitchlock control cam. Normal operation of the pitchlock assembly will occur when hydraulic pressure is restored and RPM is reduced by an increase in blade angle.

PROPELLER CONTROL ASSEMBLY (INTEGRAL OIL CONTROL ASSEMBLY)

The propeller control assembly (figure 4-9) is a nonrotating integral oil control mechanism mounted on the rear extension of the propeller barrel. The control assembly contains two major components—the pump housing assembly and the valve housing assembly. The pump housing assembly contains the hydraulic reservoirs, pumps, and valves. All mechanical and electrical connections necessary for propeller operation are made through the valve housing assembly. The mechanical connections include the linkages between the engine control system and the negative torque system (NTS). The electrical connections are for the pulse generator coil, the auxiliary pump motor, the synchrophasing system, and the anti-icing and deicing systems.

The propeller control assembly, through the use of the various pumps, valves, and control devices, supplies hydraulic pressure of proper magnitude and direction to vary the propeller blade angle as required for any selected operating condition. The propeller control assembly is serviced with MIL-H-83282, and the propeller system has a 25 quart capacity.

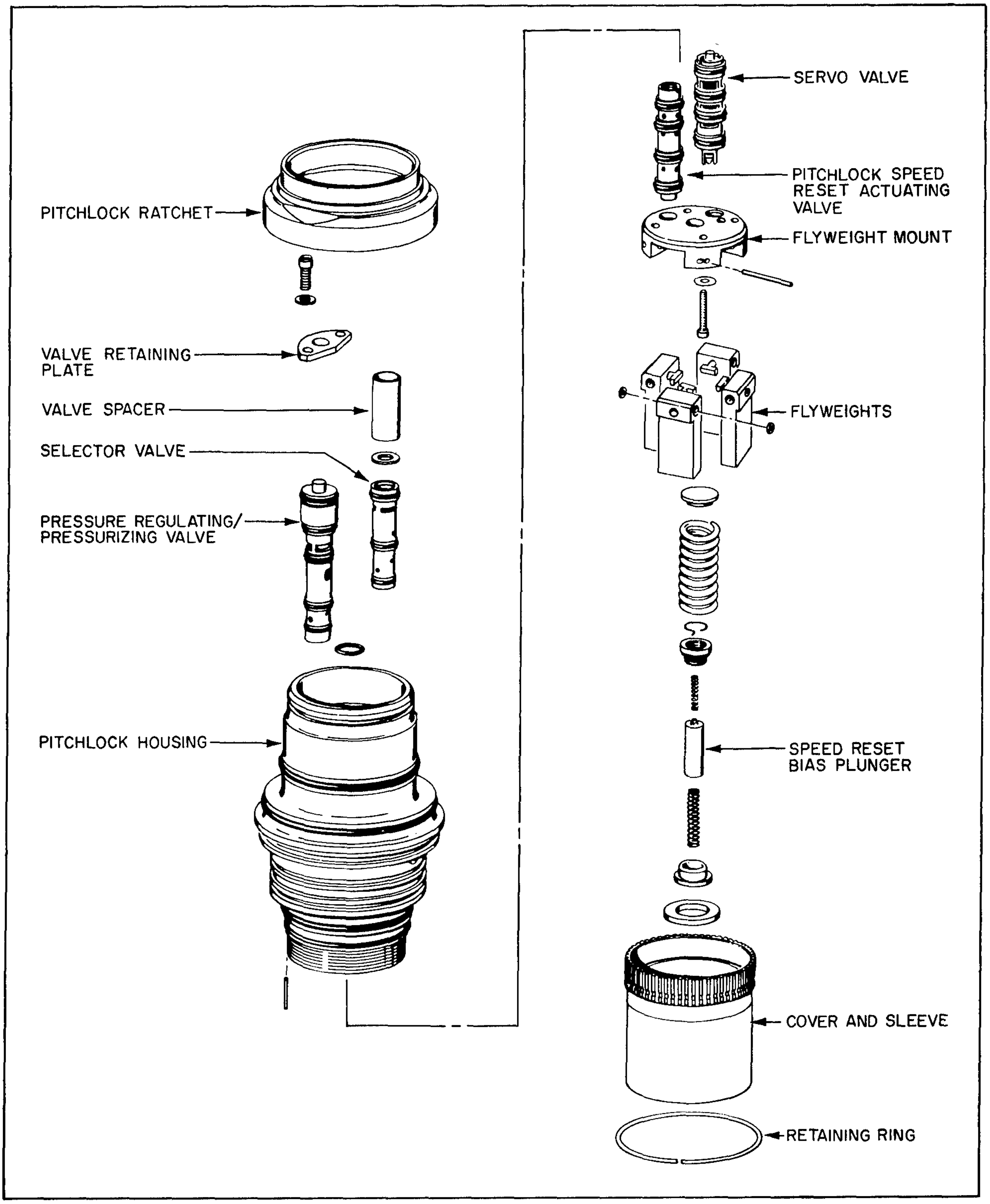


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Figure 4-8.—Propeller pitchlock regulator assembly.

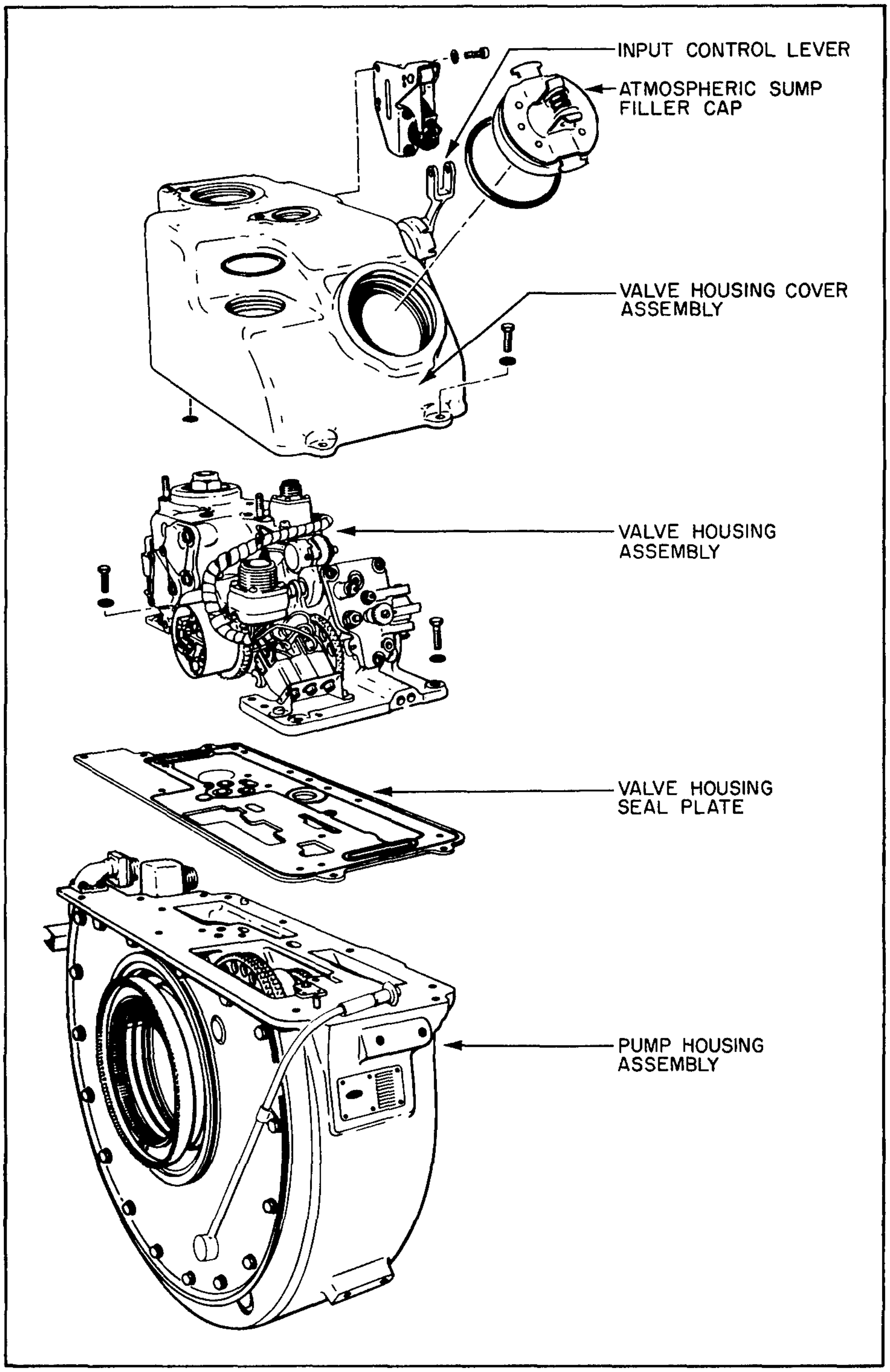

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Figure 4-9.—Propeller control assembly.

Valve Housing Assembly

The valve housing assembly is considered the brains of the propeller system, and it is mounted to the upper part of the pump housing assembly forming the propeller control assembly. The valve housing cover assembly and valve housing assembly can be detached without removing the propeller assembly from the engine.

The valve housing cover assembly consists of the input control lever, gears, adjusting mechanisms, microadjusting ring, and the disarming plunger and roller assembly. The input control lever serves as the connecting link between the engine linkage and the propeller control valve housing assembly. Access to the valve housing assembly for adjustment purposes is achieved through the atmospheric sump filler cap in the value housing cover assembly.

Major units of the valve housing assembly are the speed servo governor assembly, flyweights, speeder spring, pilot valve, feather valve, feather solenoid valve, main and standby regulating valve, high pressure relief valve, beta and speed setting lever assembly, alpha and beta pinion shafts, linkage support assembly, and the electrical branch cable. The valve housing assembly is the most complex assembly of the propeller system.

The two ranges of operation controlled through the valve housing assembly are the governing range and the taxi range. The governing range is commonly called the alpha or the flight range. The taxi range is commonly called the beta scheduling or the ground handling range. All primary propeller operations, except for feathering and unfeathering the propeller, are determined by the position of the pilot valve in the speed servo governor. Hydraulic fluid for blade angle change operation is pumped from the pressurized sump by the main pump, and standby pump (if needed), to the pilot valve chamber.

Flyweights are geared to the propeller shaft. This causes their rotation to develop centrifugal force in direct relation to the engine speed. The centrifugal force extends the flyweights outward and pushes the pilot valve toward the increased pitch position. This movement of the pilot valve is opposed by a speeder-spring force which tends to push the pilot valve toward the decrease pitch position. When speeder-spring force is equal to the flyweight centrifugal force, the pilot valve is centered in the pitch change sleeve to block pitch change hydraulic pressure from the propeller dome. Any change in the engine speed will change the outward position of the flyweight, and thus shift the pilot valve to direct pitch change hydraulic pressure to the dome.

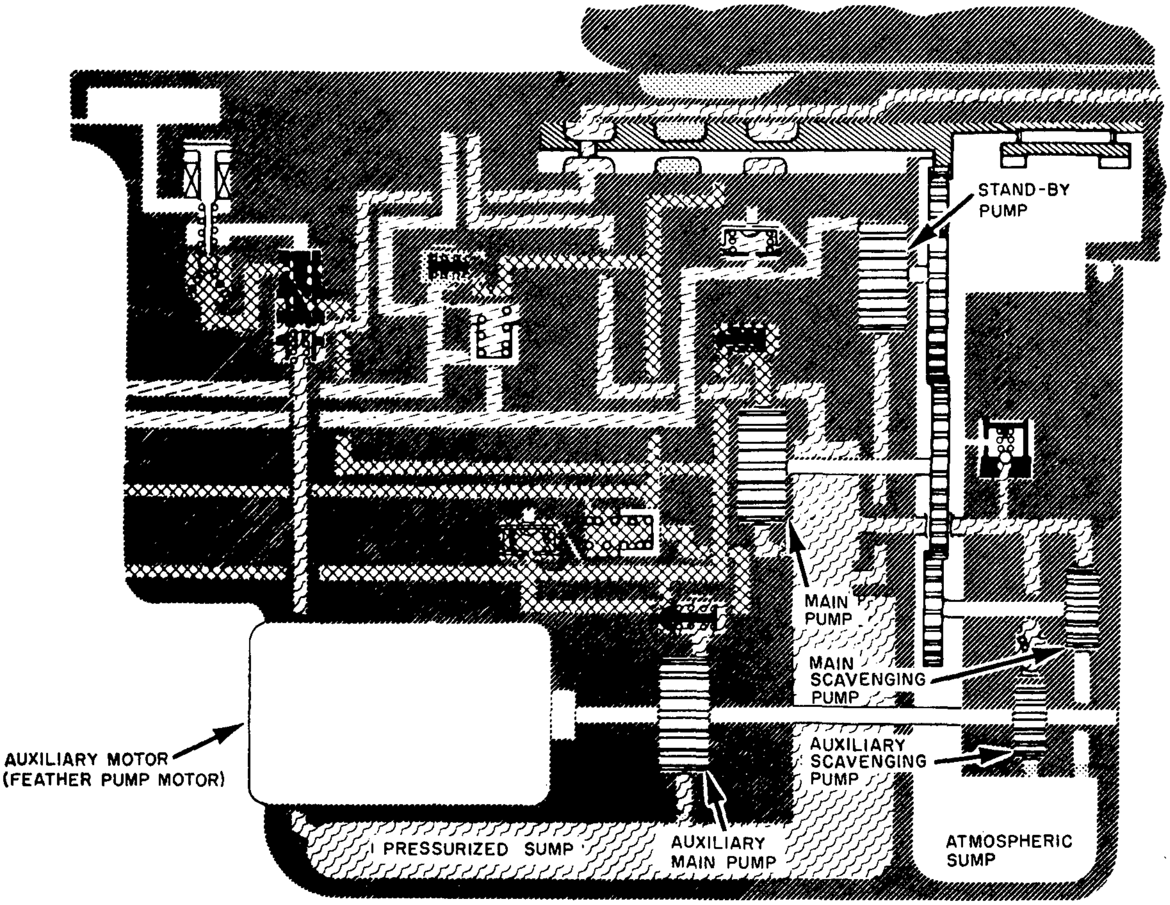
Constant speed governing is blocked out in the ground handling range. The propeller blade angle is coordinated with the position of the power lever. Interaction of the cams on the alpha and beta shaft control the position of the pilot valve in the speed servo governor. When the power lever is moved, a cam on the alpha shaft positions the pilot valve to obtain a corresponding blade angle. As the blade pitch changes, a cam on the beta shaft returns the pilot valve to a position that will maintain the blade pitch at the angle scheduled by the power lever.

Rigging pin holes are located on the valve housing assembly for rigging the valve housing to the propeller assembly and power lever. Adjustments are provided to set the mechanical governor speed and the reverse and ground handling blade angles.

Pump Housing Assembly

The pump housing assembly (figure 4-10) forms the lower part of the propeller control assembly. The pump housing contains five positive displacement gear-type pumps (three mechanically driven and two electrically driven). An externally mounted ac electric motor drives the two common shafted auxiliary pumps. Two hydraulic fluid sumps are contained in the pump housing assembly—a pressurized sump with a capacity of 6 quarts and an atmospheric sump with a capacity of 4.5 quarts. Also incorporated in the pump housing is a differential gear train used for transmitting the output of the beta feedback shaft in the barrel assembly to the valve housing assembly. A pressure cutout switch located in the pump housing serves to terminate the action of the auxiliary pumps when the feather blade angle is reached.

The three mechanically driven gear-type pumps are the main pump, the main scavenge pump, and the standby pump. The main scavenge pump, located in the atmospheric sump, supplies a constant pressure of 18 to 22 psi to the pressurized sump to prevent cavitation within the



204.119

Figure 4-10.—Pump housing assembly.

propeller control system. The main and standby pumps operate in a parallel manner. The term "main pump" denotes the duty of this pump, not its capacity. Actually, the main pump produces only half as much flow (20 quarts per minute) as compared to the standby pump (40 quarts per minute). In normal operation, the main pump flow is more than sufficient to maintain blade angle control, unless a sharp power lever movement requires a substantial pitch change. In this case, as much of the standby pump flow as needed is routed to the pitch change propeller piston. As the propeller stabilizes, the standby pump flow is phased out, and the main pump maintains the pressure required to hold the new propeller blade angle selected.

The other two pumps in the pump housing assembly are driven by an electrical auxiliary motor. One pump, known as the auxiliary scavenge pump, is connected in parallel with the gear-driven main scavenge pump. The other pump, commonly called the feather pump, is the auxiliary main pump. The feather pump is connected in parallel with the main and standby pumps. The auxiliary motor that drives these pumps is generally referred to as the feather pump motor. The feather pump motor is de-energized during normal operating conditions of the propeller system.

The feather pump is used in flight for feathering and unfeathering. It also serves to complete the feather operation after the propeller

has almost stopped rotating. An electrical motor-driven pump is needed to stop propeller windmilling completely since the output pressure of the mechanically driven pumps is reduced in proportion to the decaying propeller RPM. The feather motor power control circuit is routed through a pressure-sensing cutout switch. This switch de-energizes the motor automatically when a sharp pressure rise in the increase pitch hydraulic pressure line indicates the pitch control piston has bottomed out at its full feather position. The auxiliary scavenging pump and the feather pump are used to feather and unfeather the propeller during static ground operations.

MAJOR COMPONENT ASSEMBLY (PROPELLER BUILDUP)

Information for assembling the model 54H60-77 propeller is common to most propeller buildup. You should always refer to the appropriate technical manual for the actual assembly of the propeller system. Various components of the propeller assemblies are numbered, etched, or marked to indicate their assembled location, alignment, or recommended shim valve. These parts or assemblies must be installed in the correct position in order to obtain proper fit, clearance and balance of the propeller. Prior to buildup of the propeller, you should lightly coat barrel assembly surfaces, test bench, oil test post, and test post support with hydraulic fluid (MIL-H-83282).

The assembly of the propeller must be accomplished by using the propeller assembly and test bench with the test post support and the oil test post or its equivalent. You should install the rear cone and O-seal spacer on the oil test post. Do NOT install the preformed packing (O-ring seal). After you place the rear barrel half on the oil test post and the front cone in the rear barrel half, make sure the rear barrel half is properly seated. Next, you install the propeller hub nut without its associated preformed packings. A light torque is sufficient to retain the rear barrel half on the oil test post.

Before the propeller blades can be installed in the rear barrel half assembly, the blade preformed packings must be coated with grease (MIL-G-23827) or technical petrolatum (VV-P-236). The blade packing must be installed with the grooves facing the blade butt. You must use extreme care when stretching the packing over the blade butt and the thrust washer. You should slide the packing toward the blade tip to allow room for installation of the packing lock ring. (See figure 4-5.) The packings must be positioned so that the word "BOTTOM", which is embossed on the packing, will be located in the rear barrel half assembly when it is installed. This allows you to locate the two small holes in the blade packing which receive the ends of the special shaped rubber section seal (worm seal). (See figure 4-4.)

NOTE: You must allow 30 minutes for each blade packing to return to its original shape before installing the blade in the rear barrel half assembly.

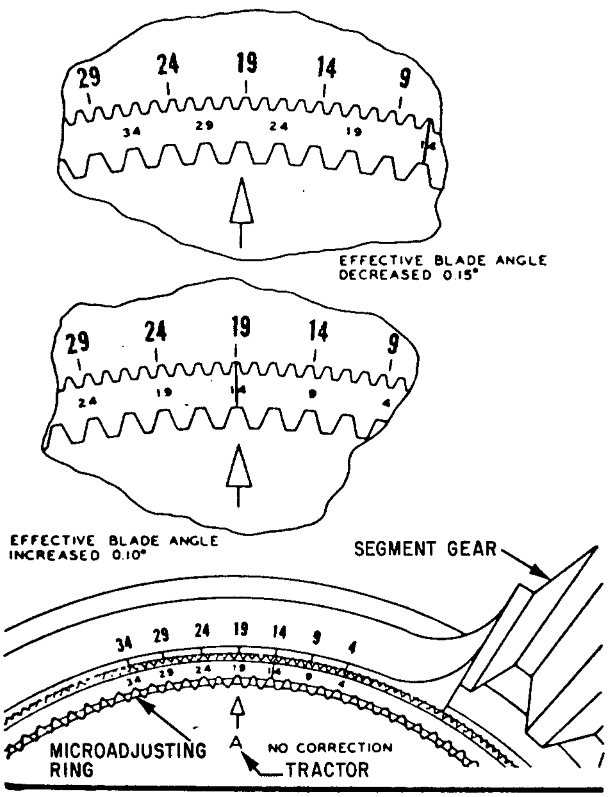
The blade packing lock ring is installed between the blade packing and the blade butt with the flat side facing the blade butt. The word "BOTTOM" is also marked on the lock ring to align the ring with the packing in the rear barrel half. The lock ring tangs must engage in the slots on the face of the blade packing to prevent the packing from rotating in the barrel assembly. The propeller blades are the next major components to be installed in the rear barrel half.

PROPELLER BLADE INSTALLATION

The numbered segment gear shim, the segment gear, and the respective microadjusting ring are installed on the butt of each propeller blade. You must align the "19" index mark on the adjusting ring and the "19" index mark on the gear segment to align with the arrow marked "tractor" on the blade housing. (See the "no correction" example in figure 4-11.)

The numbered barrel blade shim and spider shim plates are installed on each propeller blade except for the number 1 blade. The number 1 blade has a beta segment gear in place of a shim plate. The blade shim and shim plate/segment gear must be held in place with a coat of grease conforming to MIL-G-23827.

NOTE: When you look down on the rear barrel half parting surface, you can see the four blade bores are numbered counterclockwise with



204.68
Figure 4-11.—Segment gear to microadjusting ring index.

the numbers appearing on the lug adjacent to the bore.

The number 1 blade bore is adjacent to the wide spline in the center bore. The beta feedback shaft is adjacent to the number 1 blade bore. The number 1 blade is the last propeller blade to be installed in the rear barrel half.

When you are installing the blades in the rear barrel half, lift each blade in a horizontal position using the blade lifting clamp attached to a propeller hoisting sling. With a person at the propeller blade tip to steady the blade, it is guided into position in the rear barrel half. The blade is raised just high enough for the butt end to clear the barrel half. Then the blade is lowered into its barrel arm cavity. The blade packing and its lock ring are guided into position just inboard of the barrel lip so that the pins in the lock ring engage the grooves in the barrel lip at the parting surface. The two holes in the outer periphery of the packing must align with the seal groove in the barrel parting surface.

CAUTION: When installing a blade, you must exercise caution to prevent the Teflon strip around the blade from being cut by the barrel lip. Also, caution must be used to keep the beveled thrust washer against the shoulder of the barrel during installation so the blade bushing will clear the barrel stub arm.

Each blade must be pushed onto the barrel stub arm until the shim plate butts tightly against the barrel boss. When installing the number 1 blade, you must exercise care to ensure the beta segment gear teeth properly mesh with the beta feedback pinion gear. This can be accomplished by slowly turning the beta feedback shaft while pushing the blade into position. You must NOT turn the number 1 blade after installation beyond plus 95 degrees or minus 15 degrees as the beta segment gear will disengage from the beta feedback shaft pinion gear. The beveled blade thrust washers should be aligned so that the "O" marking on the washer is aligned with the "O" marking on the blade butt.

As each blade is installed and butted against the barrel boss, and while maintaining it in the horizontal position, you install one-half of the numbered split thrust washers designated for each propeller blade. The flat thrust washers are located outboard of the beveled thrust washer with the large radius outboard. The washer is rotated to position it within the rear barrel half.

NOTE: The split thrust washer halves are serialized and must be used together as a matched set with their respective barrel arm bore.

One-half of the thrust bearing retainer assembly is installed at each blade position. The retainer half is rotated until the ends are flush with the barrel parting surface. If you experience difficulty in positioning the retainer half, move the tip of the blade up or down, slightly, to find the best position for installing the retainer half. The second retainer half is installed by butting both ends against the ends of the retainer half already installed. Then rotate both retainers until the parting lines of the ends are aligned at the split line of the barrel half. After a blade and its components are correctly positioned in the rear barrel half and before installing the next blade,

support the blade near the tip with an adjustable blade support stand. When all four blades are positioned, the front barrel is ready for installation.

FRONT BARREL HALF INSTALLATION

By lifting the front barrel half, you can match the blade bore position numbers on the parting surface with those of the rear barrel half. When you install the front barrel half, use a soft-faced mallet to tap it to a snug fit above the lower barrel half. Installation may be facilitated by raising the blade tips as far as possible. Visually examine the blade packing and the packing lock ring to be sure it is started into the seal groove on both sides of each blade. Once you confirm the proper engagement, continue to tap the front barrel half to its full engagement.

NOTE: The eight barrel holes are numbered on the spot-faced surface of the front half or on the parting face of the rear barrel half so that the numbers increase in a counterclockwise direction. Each barrel bolt is marked with a corresponding number on the side of the bolt head.

The barrel bolts are inserted through the corresponding rear barrel half holes. It will be necessary to drive the bolts into place with a rubber or rawhide mallet since the plated bolts have a close tolerance fit in the barrel bolt holes to maintain alignment between the barrel halves. The extension studs are installed on the barrel bolts. Two opposite studs are tightened at the same time to draw the barrel halves together evenly. These stud extensions must be tightened to obtain a specific bolt elongation. To measure this elongation, the bolt elongation gapping pin is inserted into the cavity of the internally relieved stud extension. The pin must be seated on the end of the barrel stud bolt. An 8- to 9-inch depth micrometer is used to measure the length from the bolt head to the exposed end of the pin. The barrel bolt stud extension must be tightened until the bolt has been elongated approximately 0.008 to 0.015 inch as read on the micrometer. Do NOT exceed 0.015 inch elongation. Barrel bolts may be reused provided there is no evidence of thread damage, cracks, or elongation beyond the maximum length limit. Bolts that are damaged or exceed the maximum length must be discarded.

After the eight stud extensions have been properly installed, a cotter pin is inserted into each stud. The propeller dome assembly is the next assembly to be installed.

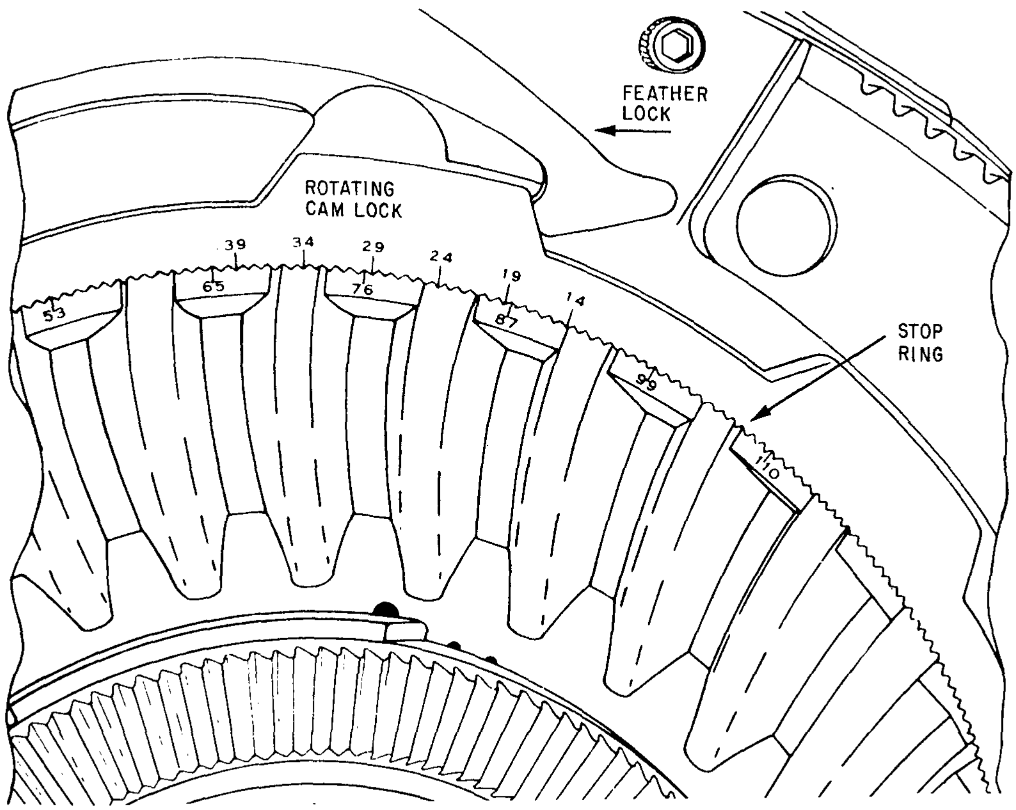
PROPELLER DOME INSTALLATION

The serial number of the dome assembly is located on the rear face of the stationary cam. The number must be identical to the propeller serial number on the rear barrel half. The rotating cam should be checked to make sure it is in the feather position. The feather position is indicated by the two feather locks being latched over the rotating cam lugs. (See figure 4-12.)

The stop ring is installed with the 19-degree spline tooth in alignment with the 86.5-degree spline tooth valley on the rotating cam, or the stop ring can be turned over and installed with the 19-degree spline tooth valley in alignment with the 87-degree spline tooth on the rotating cam.

When the preload gear shims are installed, the total thickness must be the same as marked on the front barrel shelf. The propeller blades are turned to approximately the feather blade angle setting of 86.6 degrees. The dome is lifted into position above the propeller barrel by a hoist. The dome-to-barrel preformed packing and the pitchlock regulator assembly are not installed at this time. The dome is turned to align the indexing on the dome and pin with the corresponding line on the barrel. The dome is lowered into position in the barrel. Then the retaining nut is tightened with a spanner wrench until snug. Strike the wrench handle with a heavy mallet to seal the dome on the barrel shelf and further tighten the nut to align one of its locking holes with one of the locking slots in the barrel lip. After the aligned hole and slot are marked, you remove the dome assembly and install the dome-to-barrel preformed packing. During subsequent dome installation, the dome retaining nut must be tightened to those marks.

Propeller buildup is not complete without the installation of the deicer contact ring holder assembly. The deicer contact ring holder assembly is mounted to the rear half of the barrel assembly. The deicer assembly provides the electrical continuity between the nonrotating propeller control assembly and the blade deicing elements, front spinner anti-icing and deicing elements, and the rear spinner deicing elements.



204.67

Figure 4-12.—Stop ring set at the feather angle.

A magnet assembly, used in synchrophasing operation, is mounted to the deicer contact ring holder assembly. The magnet assembly provides mounting provisions for propeller balancing. The propeller is ready for balancing at this point.

NOTE: A blade backlash check and blade resistance check must be completed before the propeller balancing checks are performed. These checks are performed using the applicable technical publication.

PROPELLER BALANCING (GENERAL)

All propeller balancing must be accomplished in a horizontal plane using the propeller balancing kit 7A100 (figure 4-13), or its equivalent. Before performing actual propeller assembly buildup and balancing, you must always

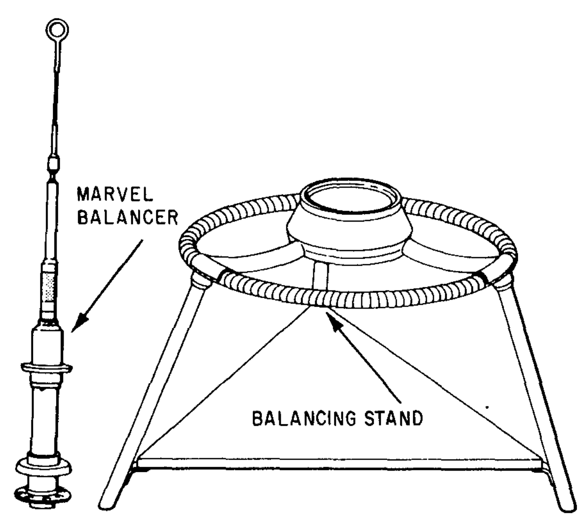


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Figure 4-13.—Propeller balancing kit (7A100).

refer to the appropriate technical publication for the propeller on which you are actually working.

Preliminary and final balance has already been completed on new and overhauled propellers before they are disassembled and shipped to an aircraft intermediate maintenance department (AIMD). It is not necessary to perform preliminary balance if final balance can be obtained first.

NOTE: The final balance check can be erroneous because of residual hydraulic fluid in the propeller dome assembly. You must ensure the dome assembly is completely drained of any residual hydraulic fluid before installing the dome assembly for the final balance check.

You must obtain horizontal balancing on all propellers during assembly. Horizontal balancing (figure 4-14) must be performed in a room free of air currents and with the propeller assembly clean and dry. The plane of the blades must be horizontal, and the blade pitch must be set at 45 degrees.

Do not install the dome cap, low pitch stop assembly, pitchlock regulator assembly, propeller hub nut, hub mounting bulkhead assembly, and their associated parts. These units are not included as part of the balancing procedure. The dome assembly, without the dome-to-barrel preformed packing and gear preload shims, is installed. The dome retaining nut is tightened down snugly past its normal locking position. Masking tape is used to hold the dome retaining nut special head screw (without its cotter pin) in place at its normal locking position.

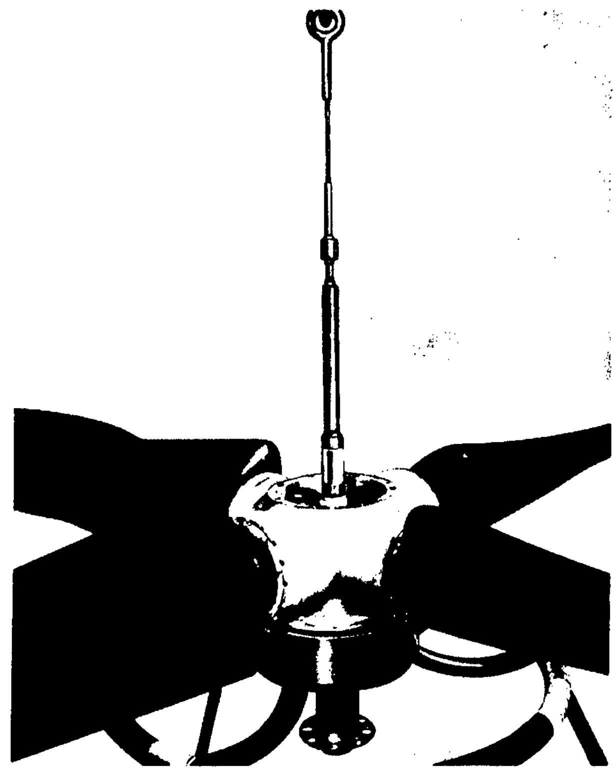

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Figure 4-14.—Propeller suspended for balancing.

FINAL BALANCE CHECK

The final balance check is obtained by adding bolts, washers, and nuts to balancing holes in the deicer contact ring holder assembly near the outer edge. If possible, bolts, washers, and nuts should be divided equally on each side of the deicer contact ring holder assembly. Similar bolts, washers, and nuts, which are painted red and already located in the balancing holes, must not be disturbed. They are used for balance of the holder assembly itself, not the propeller. Special bolts, washers, and nuts are used on the deicer contact ring holder assembly installed on the propeller. For the plastic molded holder assembly, no more than six AN960-10 washers must be used on one bolt; no more than six NAS514P1032-16 bolts and six MS20364-1032A nuts must be used.

Final balance is obtained with the propeller assembly mounted on the horizontal balance machine, with the plane of the blades horizontal, and with the dome assembly installed. The sensitivity of the balance machine must be calibrated so that any unbalance shown (figure 4-15) by the machine may be corrected or reversed by applying a restraining moment of 6 inch-ounces.

If final balance cannot be obtained because of the maximum limit on the number of bolts, washers, and nuts that can be added to the deicer contact ring holder assembly, it is necessary to obtain preliminary balance first, and then final balance. Remove the final balance bolts, washers, and nuts from the holder assembly, if they are installed.

CAUTION: The bolts, washers, and nuts which are colored red must not be removed. These

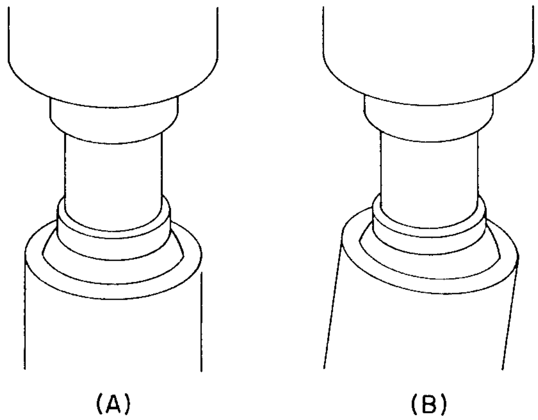

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Figure 4-15.—Indicator bushing: (A) Propeller in perfect balance: (B) Propeller is unbalanced.

are used for balance of the holder assembly itself, not the propeller.

PRELIMINARY BALANCE

If final balance cannot be obtained, preliminary balance must be obtained by installing balance washers on the blade balancing plugs of the light blades.

With the propeller suspended on the balancing stand, you should place the balance washers on the shanks of the light blades next to the outboard electric contact rings. Preliminary balance has been obtained when the propeller shows no tendency to tilt, or when tilting may be stopped or reversed by the addition of the lightest balance washer to one or more blades on the light side of the propeller.

After you have determined the amount of washers to install, remove the propeller from the balancing stand. The propeller is disassembled until the light blades have been removed. Install the required washers on the blade balance plugs, but do NOT exceed the limits shown in figure 4-16.

The propeller is reassembled and reinstalled on the balancing stand. Recheck the preliminary balance and obtain the final balance check as previously described.

After you obtain final balance, remove the special head screw taped on the dome assembly. Remove the dome assembly from the propeller using care not to disturb the 45-degree setting of the rotating cam. Remove the balancing arbor from the propeller.

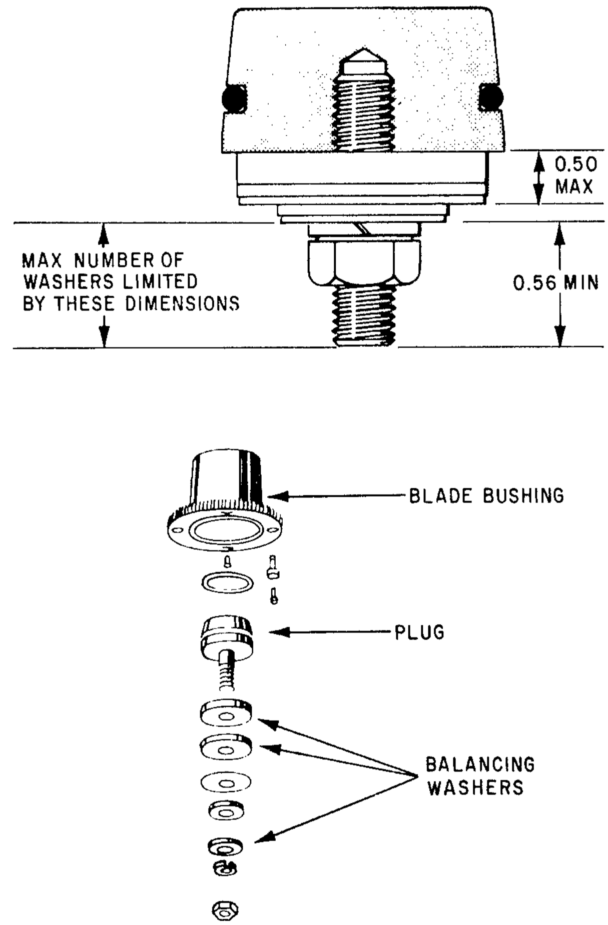

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Figure 4-16.—Propeller blade balancing.

Remove the propeller from the balancing stand. Remove the deicer contact ring assembly and the packing seal ring with its preformed packing. The propeller must be reassembled prior to performing the external and internal hydraulic leakage test.

EXTERNAL AND INTERNAL HYDRAULIC LEAKAGE TEST

Before you begin the propeller test, first verify that the propeller test equipment has been inspected, serviced, and properly assembled prior to the installation of the propeller. The propeller

must be installed on the test equipment in accordance with the appropriate technical publication before beginning the hydraulic leakage test.

After the hydraulic fluid is warmed up, exercise the propeller between the high and the low blade angles several times to purge air from both the test equipment and propeller system. Purging will avoid erratic operation during the external and internal leakage tests.

CAUTION: Attempting to initiate a decrease in propeller blade angle when the propeller is in a range from approximately 60 degrees to 15 degrees may cause the pitchlock to engage or cause damage to the ratchet teeth. If it becomes necessary to stop in this range, first increase the blade angle to above the pitchlock range, and then proceed to a decreased blade angle.

EXTERNAL LEAKAGE TEST

The test equipment used to supply the various pressures and flow requirements is the hydraulic propeller test stand GS1221. With the test stand maintaining 150 psi, cycle the propeller blades between a low-blade angle and a high-blade angle until a total of eight cycles are completed. No external leakage is permissible during the cycling.

If any external leakage occurs at the junction of the barrel half seals and the blade packings, eliminate the leakage by separating the barrel halves and adding zinc chromate putty MIL-P-8116 to the junction. You must control the amount and location of the putty to prevent it from getting into the barrel cavity. Leakage from the blade bores can be eliminated by replacing the blade preformed packing. The complete external leakage test must be rerun after any external leakage corrective work has been completed.

INTERNAL FLOW AND LEAKAGE TEST

The internal flow and leakage tests are designed to ensure the proper internal operation of the propeller system. The test equipment will supply the various hydraulic pressures to the inboard and outboard side of the dome piston, surge valve, and pitchlock mechanism ensuring smooth blade angle movement to the reverse and feather blade angles.

If internal flow and leakage requirements are not in compliance with the appropriate technical publication, you must disassemble the propeller and inspect all visible packings for damage and/or proper location.

All internal flow and leakage tests must be completed before you can issue the propeller to an operating activity. The time for discovering external/internal leakage is NOT when the propeller has been installed and is ready for final rigging.

RIGGING AND ADJUSTMENT

During the initial installation of an engine, propeller, or whenever a fuel control, coordinator, or fuel control to coordinator linkage has been replaced, a complete check of all propeller linkage settings must be made. The final propeller control linkage rigging and valve housing adjustment must be accomplished with the propeller installed.

In most cases when an engine (T56-A-14) is ready for issue (RFI) from an AIMD to a squadron, the fuel control to coordinator rigging has been completed.

A minimum of five rigging pins will be required to rig and adjust the propeller control linkage and valve housing. Refer to the appropriate technical publication for the special tool requirements.

PROPELLER CONTROL RIGGING

The propeller control assembly torque retainer lug must remain against the reduction gearbox stop assembly. This assembly is commonly referred to as the anti-rotation stops. The procedure is accomplished by attaching a 25-pound weight (minimum) to the deflector ring stiffener, located on the right side of the propeller control assembly.

WARNING: The propeller feather circuit breaker, for the propeller being rigged, must be pulled open to prevent propeller blade movement that may cause injury to personnel.

Move the power lever to the flight idle position (FI) and insert a rigging pin into the crank assembly rigging hole. At this point, the coordinator pointer, located on the lower section of the engine, must align with the 34-degree mark on the protractor. Two additional rigging pins are now inserted; one is inserted into the rear lever rigging hole (figure 4-17, view A) and the other

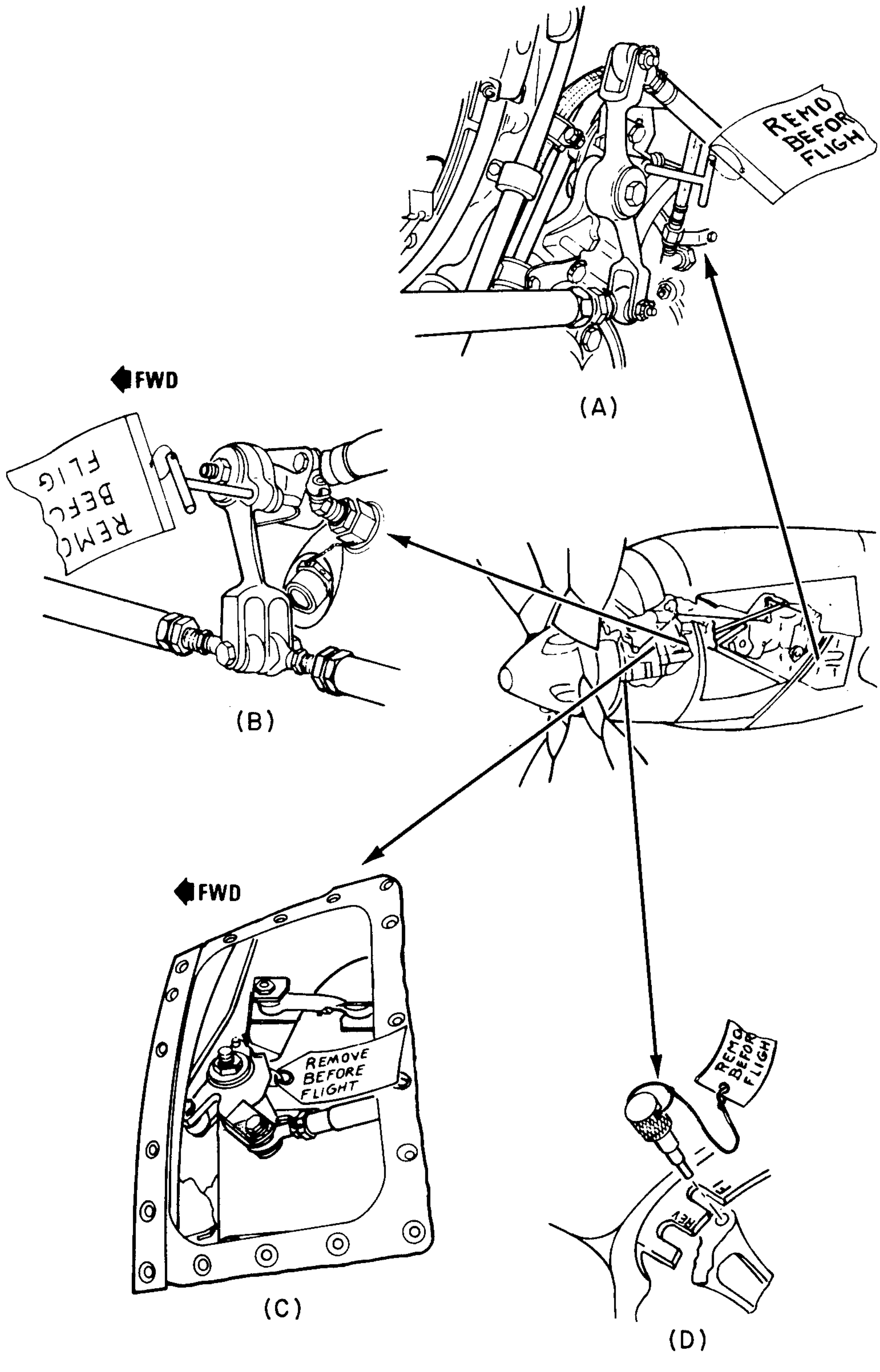

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Figure 4-17.—Inserted rigging pins: (A) in rear lever; (B) in intermediate lever; (C) in forward lever; (D) in index plate FI slot.

rigging pin is inserted in the intermediate lever rigging hole. (See figure 4-17, view B).

Adjust the coordinator, if necessary, to ensure alignment at 34 degrees, and adjust the propeller control rear and intermediate linkage rods to the correct length.

After you make adjustments to the rear and intermediate linkage rods, remove the rear lever rigging pin and insert a rigging pin into the forward lever rigging hole. (See figure 4-17, view C.) If necessary, make adjustments to the linkage rod between the forward lever and the intermediate lever.

VALVE HOUSING RIGGING

The propeller blades and power lever must be in the flight idle position and rigging pins in the intermediate and forward lever rigging holes. Remove the atmospheric sump filler cap and insert a three-step rigging pin into the alpha shaft rigging pin hole. (See figure 4-18.) At the serrated end of the forward lever, turn the serrated adjustment ring and input lever until a three-step rigging pin goes easily into the index plate flight idle (FI) slot and the input lever. (See figure 4-17, view D.) After you make adjustments to the linkage rods and input lever, remove the rigging pins and move the power lever to the takeoff position. Insert a three-step rigging pin into the index plate takeoff (TO) slot and input lever. The coordinator pointer must align with the $90 \pm 1/2$-degree mark on the protractor. If no adjustments are necessary, remove the two rigging pins.

To check the rigging at the feather position, you must pull the emergency shutdown handle and then insert a three-step rigging pin into the

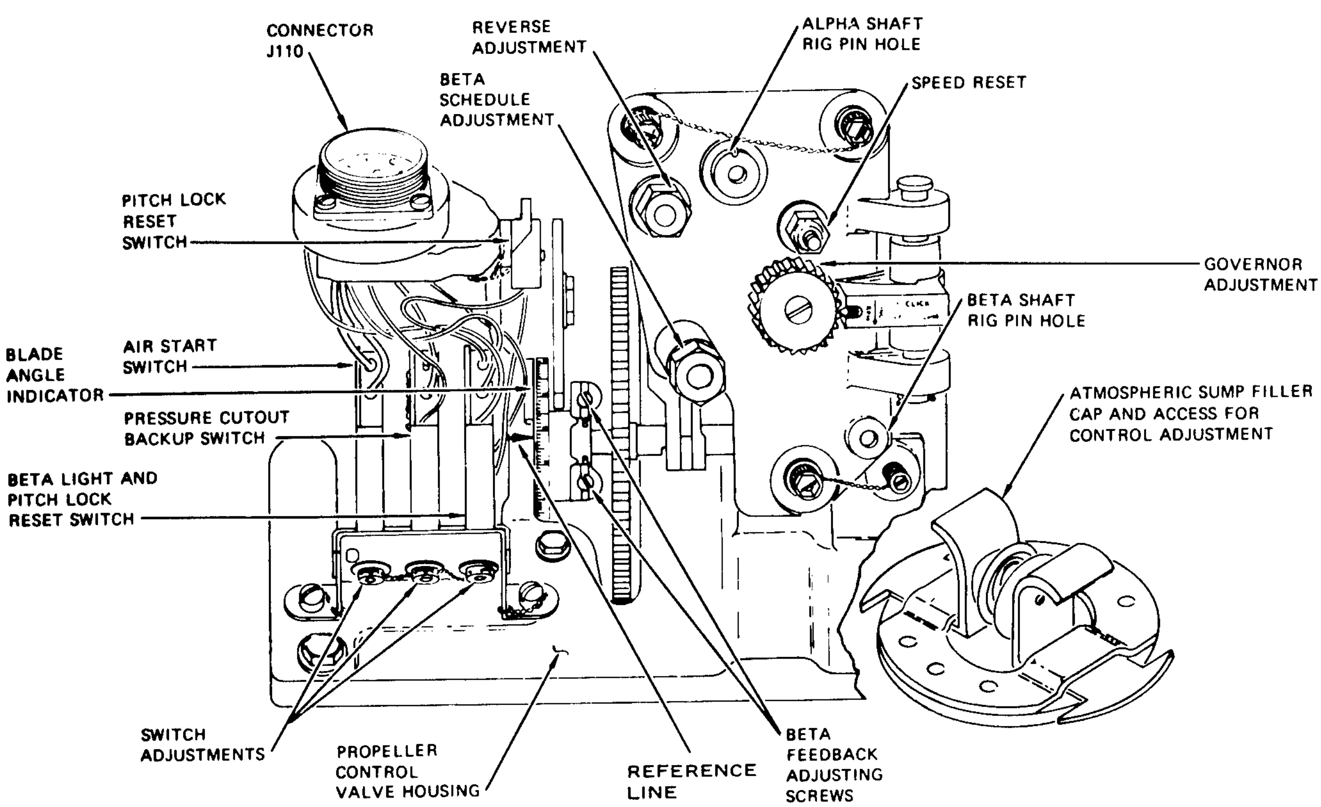

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Figure 4-18.—Valve housing assembly (rigging).

index plate feather (FEA) slot and input lever. Once any feather adjustments have been made, you must remove the rigging pins and push the emergency shutdown handle in.

After you move the power lever to the reverse position, insert a three-step rigging pin into the index plate at the reverse (REV) slot and input lever. The coordinator pointer must align with the $0 \pm 3/4$-degree mark on the protractor. Once adjustments have been made, all positions must be rechecked for proper rigging. After all rigging has been completed, check for installation of bolts, nuts, and safety wire. Torque all bolts and nuts, and safety wire all rod ends as required by the appropriate technical manual. At this point, you should remove all rigging pins, install the valve housing atmospheric sump filler cap, and remove the 25-pound weight. The spinner, afterbody, cowl panel, and engine access panel are installed and the appropriate feather circuit breaker is closed.

PROPELLER TROUBLESHOOTING

It is essential that you know the propeller system thoroughly. You should know what it is designed to do and how it fulfills its functions. You should be familiar with normal operating details of the propeller, such as in-flight and ground handling procedures.

Table 4-1 contains information to help you locate the causes of some of the more common malfunctions. The table is intended to reduce delays and maintenance downtime during troubleshooting and minimize the time lost in changing components. In preparing this table, two basic assumptions were made: (1) The flight crew followed correct operating procedures; and (2) the problem is caused by a single failure or malfunction.

Table 4-1 covers some of the malfunctions along with the probable causes and remedies for a 54H60-77 propeller installed on a P-3 aircraft.

NOTE: Troubleshooting information similar to that contained in Table 4-1 is available in maintenance instructions manuals for all aircraft, engines, and propeller systems.

Table 4-1.—Propeller Troubleshooting Chart

Malfunction	Probable Cause	Corrective Action
1. Beta light does not come on until power lever is below ground idle position.	a. Beta schedule misadjusted. b. Beta light switch misadjusted. c. Propeller control misrigged.	a. Adjust beta schedule. b. Adjust beta light switch. c. Rerig propeller control.
2. Propeller blades will not change pitch statically.	a. Auxiliary pump motor (feather motor) will not run. b. Auxiliary pump motor rotating backwards.	a. Check the three phases of 115 VAC power to motor. If available, check for 26 VDC power through contacts of de-energized feather cutout relay, to coil of feather pump relay, and to ground. Repair circuits or replace defective components. b. Reverse 2 of 3 phases.

Table 4-1.—Propeller Troubleshooting Chart—Continued

Malfunction	Probable Cause	Corrective Action
3. Excessive hydraulic fluid in atmospheric sump indicated by fluid in valve housing cavity or fluid escaping from valve housing.	a. Auxiliary motor scavenge pump malfuction.	a. Replace propeller control.
4. Loss of propeller fluid through leakage from propeller assembly (blades, dome, barrel).	a. Defective or missing dome cap seal. b. Defective or missing dome-to-barrel seal. c. Defective blade seals.	a. Replace dome cap seal. b. Replace dome-to-barrel seal. c. Replace propeller assembly.
5. Loss of propeller fluid through leakage from rear of barrel tail-shaft extension.	a. Missing or defective seal forward of spacer. b. Missing rear cone.	a. Replace seal forward of spacer. b. Deface (saw cut/drill) propeller shaft and replace reduction gear box.
6. RPM fluctuation, overspeed, and underspeed, during take-off application.	a. Propeller loading and power lever application. b. Propeller improperly serviced. c. Mechanical governor misadjusted. d. Dome seal leakage. e. Propeller control internal leakage. f. Valve housing troubles.	a. Normal condition when associated with these conditions. b. Service propeller. c. Adjust mechanical governor to 100 (±0.2) percent. d. Reseal dome. Repair as required. e. Replace propeller control. f. Replace valve housing.
7. RPM overspeeds when positioning power lever to flight idle on inflight NTS check. Power lever binding may also occur.	a. Propeller valve housing rigging misadjusted at flight idle. b. Power lever rigging from flight station to propeller misadjusted.	a. Adjust propeller valve house rigging. b. Adjust power lever rigging.

Table 4-1.—Propeller Troubleshooting Chart—Continued

Malfunction	Probable Cause	Corrective Action
8. Pitchlock does not operate.	a. Pitchlock reset is energized. b. Dome or pitchlock stationary cam out ring misindexed. c. Subsequent to propeller replacement check for misaligned barrel halves. d. Synchrophaser unit defective. e. Test cables shorted. f. Time delay relay troubles.	a. With the propeller blades at flight idle or above, check for ground in circuit from pitchlock reset solenoid. b. Install correctly (index ring to centerline of No. 2 blade). c. Replace propeller. d. Replace unit. e. Remove/replace test cables. f. Replace time delay relay.
9. NTS light ON with power lever at takeoff position.	a. Power lever rigging misadjusted. b. NTS switch misadjusted.	a. Adjust power lever rigging. b. Adjust NTS switch.
10. Propeller will not feather with engine emergency shutdown handle, but will feather with feather button.	a. Feather button does not pull in. b. Emergency shutdown handle misrigged.	a. Check for 26 VDC power through contacts of emergency shutdown handle to coil of emergency shutdown relay and to ground. Check for 26 VDC power through contacts of energized emergency shutdown relay, through holding coil of feather button, and to ground. Repair circuit or adjust or replace switches on shutdown handle or replace shutdown relay. b. Rerig emergency shutdown handle.
11. Propeller will not feather with feather button or engine emergency shutdown handle.	a. Propeller control. b. Emergency shutdown handle misrigged.	a. Check the auxiliary pump motor and feather solenoid as previously described. If OK, remove propeller and check feathering action on hydraulic test bench. If OK, replace propeller control. b. Rerig emergency shutdown handle.

Table 4-1.—Propeller Troubleshooting Chart—Continued

Malfunction	Probable Cause	Corrective Action
12. Propeller feathering action stops at blade angle of 72 to 76 degrees vice 86.5 degrees.	a. Pressure cutout switch circuit ground or pressure setting too low.	a. Check circuit from pressure cutout backup switch to pressure cutout switch and to ground. If grounded outside of propeller control, repair circuit. If grounded inside valve housing, replace valve housing. If circuit is satisfactory, replace propeller control.

CHAPTER 5

JET ENGINE TESTING AND OPERATION

For a jet aircraft engine to operate properly, it must be adjusted properly. The checks for proper adjustment can best be made during controlled operation of the engine. The various types of test facilities or test cells are designed for service testing of the jet engine according to procedures and manuals published by the Naval Air Systems Command (NAVAIRSYSCOM). Most engine test cells are used at the intermediate- or depot-level maintenance facilities.

Operators of these test facilities are required by OPNAVINST 4790.2 (Series) to be certified by completion of at least one of the following three basic methods of operator training:

1. Completion of formal training at a Naval Air Rework Facility (NARF) school, based on the specific model of test facility.
2. Completion of on-site training provided by a Naval Air Engineering Service Unit (NAESU) engineer.
3. Completion of on-the-job training (OJT) under the direct supervision of a senior petty officer or civilian technician who is a certified test stand operator and who has been designated by the activity's commanding officer to provide this training.

All certified test cell operators must hold a valid support equipment (SE) license and ensure that each particular engine and engine test system is indicated on the license. Refer to OPNAVINST 4790.2 (Series) for training and licensing procedures.

ENGINE TEST CELLS

Engine testing is accomplished primarily in a test cell or house that is fully equipped to measure all of the desired engine operating parameters. The building is usually of concrete construction and contains both the control and engine rooms, although in some installations only the control or the instrumentation room is enclosed. Most of these cells have noise silencers installed in the inlet stack for noise suppression and a water spray in the exhaust section for cooling. Many of the test cells incorporate computers to automatically record all instrument readings and correct them to standard day conditions. A typical enclosed test facility is described in the following paragraphs. To complete engine test cells coverage, portable universal engine runup test systems, testing consoles, and the engine test log sheets are also described.

ENCLOSED TEST FACILITY

The test equipment is capable of handling 30,000 pounds of jet thrust during performance tests. The test facility building configuration has an engine mass airflow capacity of 180 pounds per second, or approximately 17,000 pounds of thrust, including afterburner operation.

The complete test equipment consists of nine interconnected major assemblies. These assemblies are installed in the test facility building. The test facility building is constructed of reinforced concrete throughout. Removable concrete panels are provided in the primary intake and exhaust stack systems to permit airflow and acoustic expansion of the test facility to a 30,000-pound thrust capacity.

The test cell consists of horizontal primary and secondary air intake stacks, a vertical exhaust stack, an engine room, and a spray room. Immediately adjacent to the test cell is a one-story structure containing an engine control room, a pump room, and a fuel-filter room.

The pump room contains a cooling water pump, an air compressor, a 28-volt dc generator set, and a 115-volt, 400-Hz ac generator set for operation of the test facility. In addition, the pump room contains batteries for operation of the CO_2 fire-extinguishing system. The fuel-filter room contains a fuel flow measuring package in addition to a fuel-filter separator.

The test facility operates on the principle that the accumulation of sufficient data for comparison with known or desired optimum values will satisfactorily indicate the relative service of an engine under test. To accomplish this result, you compare the engine performance and test cell environmental data to standard day performance criteria for the engine model being tested. Various controlling, sensing, and indicating systems are provided to accurately measure engine performance and test cell environmental conditions during the test.

Major Components

A brief discussion of the purpose of each of the major assemblies is given in the following paragraphs. System description and operating principles are also discussed.

VARIABLE HEIGHT STAND ASSEMBLY.—The variable height stand assembly, or thrust bed, is utilized to support, restrain, and position the engine in the desired testing attitude. This assembly is also used to transfer the engine from the trailer to the thrust bed. Mounting rails for the engine, hydraulic controls, an air-hydraulic booster, hydraulic lift cylinders, a pivoting mechanism, and provisions for mounting thrust-bearing equipment are included with the variable height stand.

The mounting rails (thrust bed) are reinforced and drilled to accommodate the clamps that locate and restrain the engine in its optimum testing position. A link rod couples each clamp to an eye on the appropriate engine maintenance and test adapter. The thrust bed is suspended on four flexure plates, which permit the thrust bed load beam to actuate the thrust measuring system.

Limit stops are provided on the load beam to prevent excessive movement of the thrust bed during engine installation and removal procedures. When the forward adjustable limit stop is utilized to completely limit movement of the thrust bed, the limit stop must be readjusted prior to engine operation to permit normal operation of the thrust measuring system. Through use of the hydraulic controls, the thrust bed can be raised or lowered to match the height of the trailer when rolling the engine onto the thrust bed or when positioning the engine so it can be operated on the required 5-foot center line from the engine floor. The first stage augmeter orifice center lines cross at approximately 5 feet above the floor.

ENGINE TEST CONNECTOR PANEL ASSEMBLY.—The engine test connector panel assembly (connector panel) is provided as a terminal board for interconnecting the engine with the test equipment.

CONTROL BOARD INSTRUMENT ASSEMBLY.—The control board instrument assembly (control board) provides for central control of the engine and the test equipment. The necessary indicating and recording instrumentation for monitoring engine and test facility conditions is located here. An operator can exercise complete control of the test facility from this control board.

EXHAUST AUGMENTER ASSEMBLY AND EXHAUST GAS COOLING SYSTEM ASSEMBLY.—The exhaust augmenter assembly (augmenter) and the exhaust gas cooling system assembly (exhaust cooling system) are provided to ensure proper disposition of engine exhaust by controlling exhaust gas, flow characteristics, and temperature. These factors can be monitored, both manually and automatically, with the controls and instrumentation installed. For example, if exhaust stack temperatures in excess of a preset temperature are experienced during afterburner operation, the afterburner is automatically cut off by a latching relay. When this occurs, the afterburner cannot be relit until safe temperature conditions prevail and the relay is reset. Provisions have been made for manually overriding the exhaust stack temperature control system should it fail or otherwise prove inadequate.

The principle of automatic safety control is a built-in characteristic of test equipment. An interlock system has been provided for automatic

engine shutdown or prevention of engine start when the following conditions prevail:

1. Inadequate water pressure to maintain exhaust gas cooling, except when bypassed by the WATER-FUEL INTERLOCK switch.
2. Thrust bed not locked and interlocked in height position.
3. Front door key not in control panel lock, or door unlocked without utilization of front door bypass switch and rear door key not inserted in control panel lock.
4. Primary air supply fire curtain not open.
5. CO_2 fire-extinguishing system energized, either manually or automatically.
6. Electric power failure.
7. System-wide loss of compressed air supply.

FUEL SYSTEM MONITORING ASSEMBLY.—The fuel system monitoring assembly (fuel system) consists of the devices required for fuel filtration, flow and specific gravity measurement, and flow control.

ENGINE OIL RESERVOIR AND ENGINE AUXILIARY LUBRICATING OIL COOLING SYSTEM COMPONENT ASSEMBLY.—The engine oil reservoir and engine auxiliary lubricating oil cooling system component assembly (lubricating system) provides a 20-gallon engine oil reservoir and an auxiliary means of cooling engine oil to a controlled temperature.

COMPRESSED AIR COMPONENT ASSEMBLY.—The compressed air component assembly (compressed air system) provides pneumatic power, air system hardware, and pneumatically operated controls and actuating cylinders necessary for remote control of numerous devices throughout the test facility.

INTERCOMMUNICATION SYSTEM.—The intercommunication system provides communication between the control room and the test cell. As installed, the system consists of a master station in the control room and one remote station each at the test cell observation port and the test cell. The master station is designed to handle six additional remote stations, if required at some future time.

ELECTRIC POWER AND OTHER TEST FACILITY FEATURES.—Three primary sources of electric power are provided for the test facility. They are as follows:

1. Main service to facility: 120/208-volt ac, 3-phase, 60-Hz, 4-wire.
2. Motor-driven generator test set: 28-volt dc.
3. Motor-alternator test set: 115-volt ac, 1-phase, 400-Hz.

Electric power, developed by any test engine equipped with an engine-driven alternator, is not utilized for test purposes. If power is required by the applicable engine test instructions, a water-cooled load bank provides for application of a token 5-kva alternator load, consisting of immersion heater elements.

Various components are provided to support or supplement the test equipment. The major components are facility fuel supply tanks; fuel pumps and motors; water pump controls, valves, motor control center and associated electrical equipment; 115-volt ac, 1-phase, 60-Hz lighting switch panel; and CO_2 fire-extinguishing system. Engine harness and hookups between engine and connector panel, as well as special test items, are the responsibility of the using activity.

Test Equipment System

The major assemblies of test equipment discussed in the above paragraphs are integrated into the total functioning and operation of the test facility. For example, numerous test equipment items are located in, or integrated with, portions of the fire-extinguishing, fuel, water supply, and electrical systems, which are, in turn, part of the test facility. For the purpose of clarifying the functions of the major assemblies of the test equipment and their relationship to operation of the test facility, the assemblies are considered to be part of the following systems:

1. Thrust bed positioning system
2. Thrust measuring system
3. Engine test connector panel system
4. Control board system
5. Interlock system
6. Exhaust augmenter system
7. Exhaust gas cooling system

8. Fuel system
9. Engine lubricating system
10. Compressed air system
11. Intercommunication system
12. Engine starting and ignition system
13. Electrical power system
14. CO_2 system

THRUST BED POSITIONING SYSTEM.—The thrust bed positioning system is essentially a pneumatic-powered, hydraulic oil-driven device capable of raising and lowering the test engine to any attitude within operating range. Operating controls are mounted on the left front A-frame of the thrust bed.

In addition to supplying lifting force for height positioning of the thrust bed, oil pressure is used to drive the calibration cell cylinder whenever controlled thrust pressure is required.

THRUST MEASURING SYSTEM.—The thrust measuring system becomes operative when the thrust button is acted against by the load cell as a result of slight forward motion of the engine under power. If desired, the load cell may be preloaded by the preload unit. As thrust is developed by the engine, the pressure between the button and the cell produces an electric potential within the cell. The electric current thus established is connected to the thrust measuring circuit box, where it is amplified sufficiently to power the thrust indicator. The thrust indicator is calibrated to read directly in pounds of engine thrust.

ENGINE TEST CONNECTOR PANEL SYSTEM.—The engine test connector panel system contains 75 essential connectors and fittings for interconnecting the test engine, control board, and the remaining test equipment. High- and low-pressure quick-disconnect fittings (self-sealing) for pressure lines and capped electrical fittings for electrical lines are provided.

CONTROL BOARD INSTRUMENT SYSTEM.—The control board instrument system consists of four panels designated as panel A, panel B, panel C, and panel D. (See figure 5-1.) The panels contain instruments and control components required to properly operate the test equipment to functionally test turbojet engines.

The electronic counter is an instrument designed to count specific events during variable intervals of time. As installed on the control board, it is used to indicate engine rotor revolutions per minute.

INTERLOCK SYSTEM.—The interlock system is a simple series circuit consisting of manual and automatic switches, relays, and fuses.

An electric motor-driven test generator provides all 28-volt dc power used by the interlock system and the test equipment. It is started with a 28-volt dc motor-generator set switch, which opens and closes the main relay of the generator output line. The 28-volt engine master switch is the master input switch for the 28-volt system, including the interlock system. When this switch is raised to the ON position, its mating green pilot light is illuminated and engine master relay is energized. Power is then available at the 28-volt engine control switch, having arrived by way of the closed contacts of a normally open relay.

NOTE: All ON and OFF switches installed on the control board are positioned so that their respective ON positions in relation to the lower edge of the applicable panel are established with the toggle raised.

Control point No. 1 consists of a CO_2 pressure switch and mating green pilot light. The switch is a manual reset switch, remotely located at the connector panel in the test cell and is programmed to seek the OFF position whenever the test cell of the CO_2 fire-extinguishing system is energized manually or automatically. If the pressure switch contacts are broken, they must be manually reset to the ON position before the interlock system circuit can be completed.

Control point No. 2 consists of a front door key operated switch and two mating pilot lights. The key that operates the switch is the key locking the front door of the test cell; this key cannot be removed from the door lock mechanism until the door is locked.

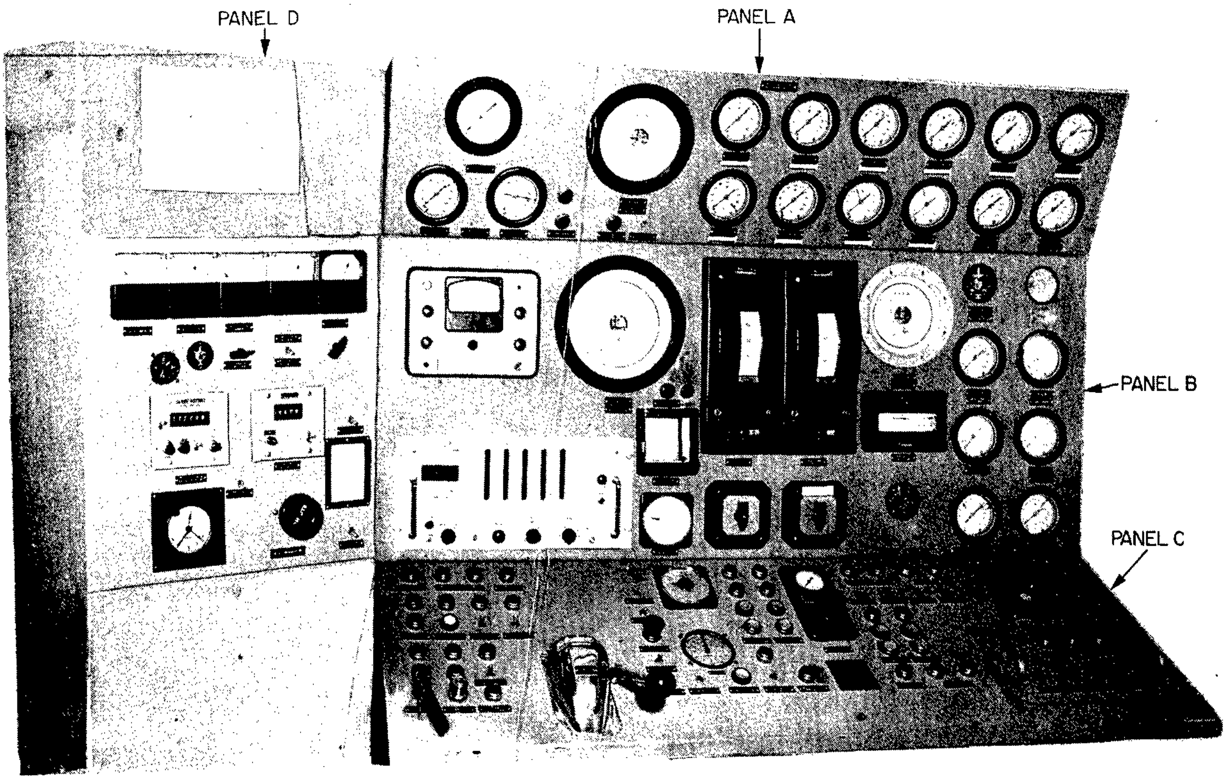

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Figure 5-1.—Control board.

Before the interlock system can be energized by the switch, the key from the front door must be removed and brought to the control room for use with the switch. The two mating pilot lights indicate the key switch position—green for CLOSED and red for OPEN.

Control point No. 3 consists of a front door bypass switch and mating red pilot light. This switch is provided to permit removal of the front door key from the switch at control point No. 2. The key cannot be removed without placing the switch in the OPEN position so that the key may be used to open the front door when it is necessary for authorized personnel to attend to the engine or test equipment during periods of engine operation.

EXHAUST AUGMENTER SYSTEM.—The exhaust augmenter system consists of two stages. Both stages are adjustable to meet specific engine exhaust conditions.

The first stage exhaust augmenter is located in the forward test cell wall of the spray room. The horizontal center line of the first stage and the second stage exhaust augmenter is approximately 5 feet above the test cell floor. The first stage augmenter receives the exhaust discharge of the test engine and by venturi action tends to draw such exhaust to the second stage augmenter in the spray room. The first stage augmenter spray ring, which is controlled manually from the control board, is included in the first stage.

The size of the first stage augmenter orifice and the distance from the plane of the engine exhaust exit nozzle to the mount of the insert should be correlated for each engine model to obtain true engine performance and proper control of secondary airflow. Improper sizing and positioning of

the first stage augmenter may result in the following:

1. Excessive turbulence in the region of the exit nozzle.

2. Excessive buildup of exhaust back-pressure.

3. An increase in exhaust gas temperature.

4. Loss of thrust.

5. Insufficient or excessive secondary airflow. (Excessive secondary airflow produces ram drag across the engine; and with operation of high thrust engines, an excessive test cell depression results.)

The second stage exhaust augmenter is located in the spray room. A movable collector section is provided along with a flat orifice plate. Movement of the collector section, and the indexing of the orifice plate, afford quantity adjustment of the airflow from the secondary air intake stack through the second stage augmenter. The lateral diffusing vanes are water cooled and afford additional exhaust gas cooling. Discharged exhaust gases, mixed with spray water and air, pass from the second stage augmenter into upward diffusing vanes. These vanes are located at the base of the exhaust stack and upward and out from the exhaust stack.

EXHAUST GAS COOLING SYSTEM.—The exhaust gas cooling system is composed of the following basic, series-connected components.

1. Water supply
2. Pump No. 1
3. Shutoff valve
4. Water heater tank
5. Bottom header of lateral diffuser
6. Exhaust gas cooling and diffusing vanes
7. Numbers 1, 2, 3, and 4 spray-ring air cylinder-actuated valves
8. Numbers 1, 2, 3, and 4 spray rings

The exhaust gas cooling system is supplied by a single water pump; however, most of the equipment necessary for a future two-pump supply system has been incorporated to assist in installation of such a system, if required. This equipment is discussed in the overall explanation of the exhaust gas cooling system. The overall explanation also includes any equipment not currently installed but required for a two-pump system, as well as any features specifically resulting from the current dual system with only one pump supplied. With only one water pump, for example, there is insufficient capacity to flood No. 3 and No. 4 spray rings; therefore, these rings and the pump have been made inoperative.

FUEL SYSTEM.—The fuel system consists of two 10,000-gallon underground fuel tanks, two fuel pumps, two motor-driven fuel line valves, the fuel system monitoring assembly, and various controls and pilot lights at the control board. The fuel system is interlocked to the basic interlock system, to the CO_2 fire-extinguishing system, and to the exhaust gas cooling system.

ENGINE LUBRICATING SYSTEM.—The engine lubricating system consists mainly of two major component assemblies—the engine oil reservoir system and the engine auxiliary lubricating oil cooling system.

The engine oil reservoir system is made up of a 20-gallon tank equipped with suitable fittings, a sight gage, and breather vent. The engine lubricating oil is supplied from the storage tank, by way of the oil outlet to the engine lubricating system and back to the tank, through the oil inlet. The amount of oil in the tank can be readily determined by observing the oil level in the sight gage. The storage tank is located at an extension of the connector panel in the test cell.

The auxiliary lubricating oil cooling system is provided for use as required by specific engines. Refer to applicable engine test instructions. It consists of an oil temperature regulator valve, a heat exchanger, and suitable plumbing. Water, by way of the oil temperature regulator valve, passes through the cooling elements of the lubricating oil heat exchanger, which is used

to cool the engine oil circulating through the exchanger. The temperature of the oil returned to the engine is sensed by the oil temperature regulator valve by a sensing bulb installed in the heat exchanger oil line. The oil temperature regulator reacts to the bulb signal by positioning a poppet valve to either increase or decrease water flow through the heat exchanger to maintain the oil outlet temperature between proper limits. The oil temperature regulator is provided with a handwheel so that the temperature range may be adjusted, if required, to maintain outlet oil temperature within the allowable range. The water utilized for cooling the engine lubricating oil flows from the main water supply system to the load bank water tank (containing heating elements) and then to the oil temperature regulator valve.

COMPRESSED AIR SYSTEM.—The air compressor (a two-stage, air-cooled, electric motor-driven system) is located in the pump room and is controlled by a switch located on the master control center in the control room. Two plug-in outlets supply unregulated compressed air for test cell utility purposes as required. Air filtration and partial dehydration are accomplished by two float-type air filters for two main branch supply lines. The pressure to each branch line is controlled by two manually set air pressure regulators. Beyond the pressure regulators, the air system branches off to the various control components for other major systems, such as the fuel system and the exhaust gas cooling system.

INTERCOMMUNICATION SYSTEM.—The intercommunication system consists of an eight-station intercom master in the control room, a suitable amplifying system, and two remote stations equipped with trumpets and microphones. The six spare station switches at the master control are not used as installed. The master unit is equipped with a volume control, a push-to-talk button, and push-to-talk lock button. Remote stations are equipped with push-to-talk buttons only. Station No. 1 is located in the test cell; station No. 2 is located at the test cell observation port.

ENGINE STARTING AND IGNITION SYSTEM.—The starting of a jet engine or any other type of gas turbine engine requires that the engine be rotated at a speed that will provide sufficient air intake for the required fuel-air ratio. Provisions are made for energizing the ignition system to fire the spark (igniter) plugs at the proper time, and for the engine to be accelerated until the power developed by the turbine is adequate for self-sustained rotation. Initial rotation of the engine during starting may be accomplished by use of either an electrically operated starter motor or a compressed air-operated air turbine starter motor. The electric starter motor requires a source of dc voltage. The air turbine motor requires a source of compressed air.

ELECTRIC POWER SYSTEM.—The electric power system consists basically of two sources of power—an electric motor-driven alternator set, which provides 115-volt,, 1-phase, 400-Hz power; and an electric motor-driven test generator, which provides 28-volt, dc power.

CO_2 SYSTEM.—The CO_2 fire system for the test facility consists of a 2-ton CO_2 storage tank, which incorporates a refrigeration system to maintain the liquid carbon dioxide at the proper storage pressure; a handwheel-operated shutoff valve on the dip tube of the storage tank; pressure-operated control valves for quickly releasing the carbon dioxide; a piping system terminated in the CO_2 discharge nozzles, strategically located in the protected areas; and various controls, relays, thermostats, alarm gongs, spurt and flood push buttons, and pressure-operated switches. For complete fire control coverage, the CO_2 system is electrically linked to the interlock system and pressure linked to the main fuel line valve of the engine fuel supply.

The CO_2 storage tank is designed for maximum working pressure and is equipped with a complete Freon (F-12) refrigeration system, which is automatically controlled by an internally mounted pressure switch. The refrigeration system maintains a nominal storage tank pressure. The storage tank is protected by a safety assembly consisting of a dual switching valve, which, when in the normal position, places in service one auxiliary automatic refrigeration valve, one safety valve, and one high pressure relief disk. The safety devices provide complete protection against abnormally high tank pressures. An abnormally high pressure usually results from power or

compressor failure continuing over a period of several hours.

PORTABLE UNIVERSAL ENGINE RUNUP TEST SYSTEMS

There are several different models of universal test cells in use. Figures 5-2, 5-3, 5-4, and 5-5 show some of the more commonly used test cells which provide the aircraft maintenance activities with a portable and universal system for the operational and functional testing of jet aircraft engines.

These systems perform the basic function of checking all the engine performance characteristics against the engine manufacturer's operational parameters as approved by NAVAIRSYSCOM. The test cells display engine temperatures, vibrations, fuel metering, fuel flow pressures, thrust, lube oil temperatures and pressure, compressor pressure, hydraulic oil pressure, anti-ice pressure, turbine rpm, and position indications such as nozzle and stator vane and throttle.

NOTE: These test systems may be used at any site location that has been provided with adequate tie-downs (either concrete embedded or buried expansion anchors).

TESTING CONSOLE

Some engines require special testing consoles. The console provides the electrical circuits (not normally found in a test cell)

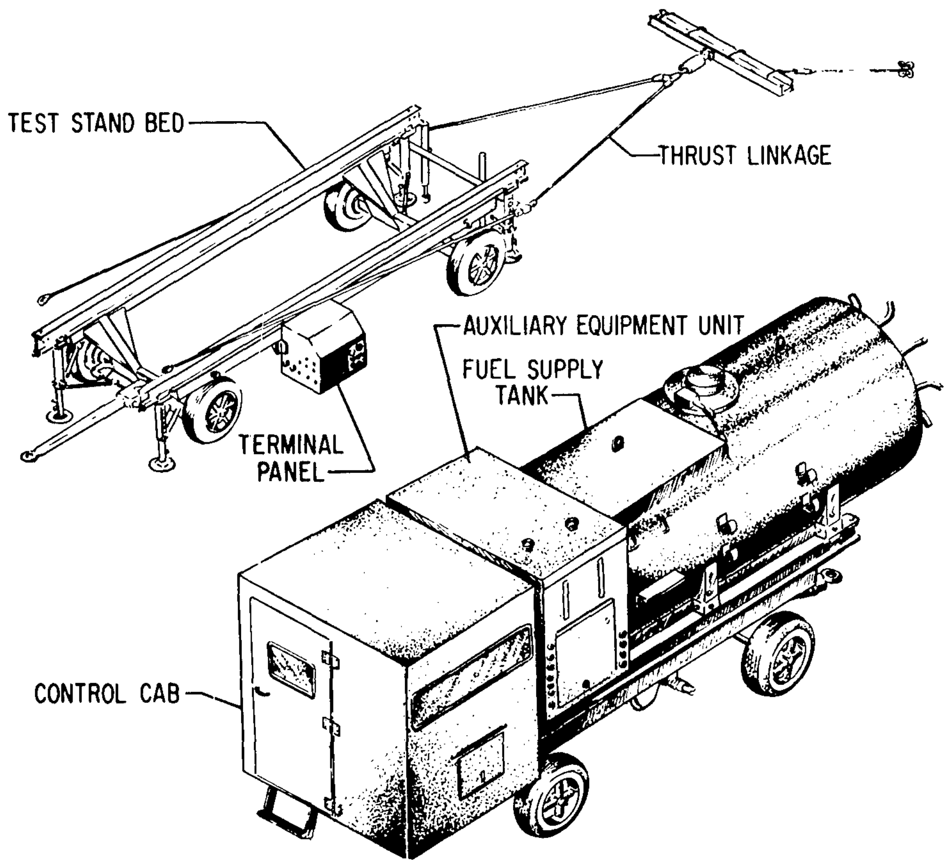

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Figure 5-2.—Portable universal engine runup test system.

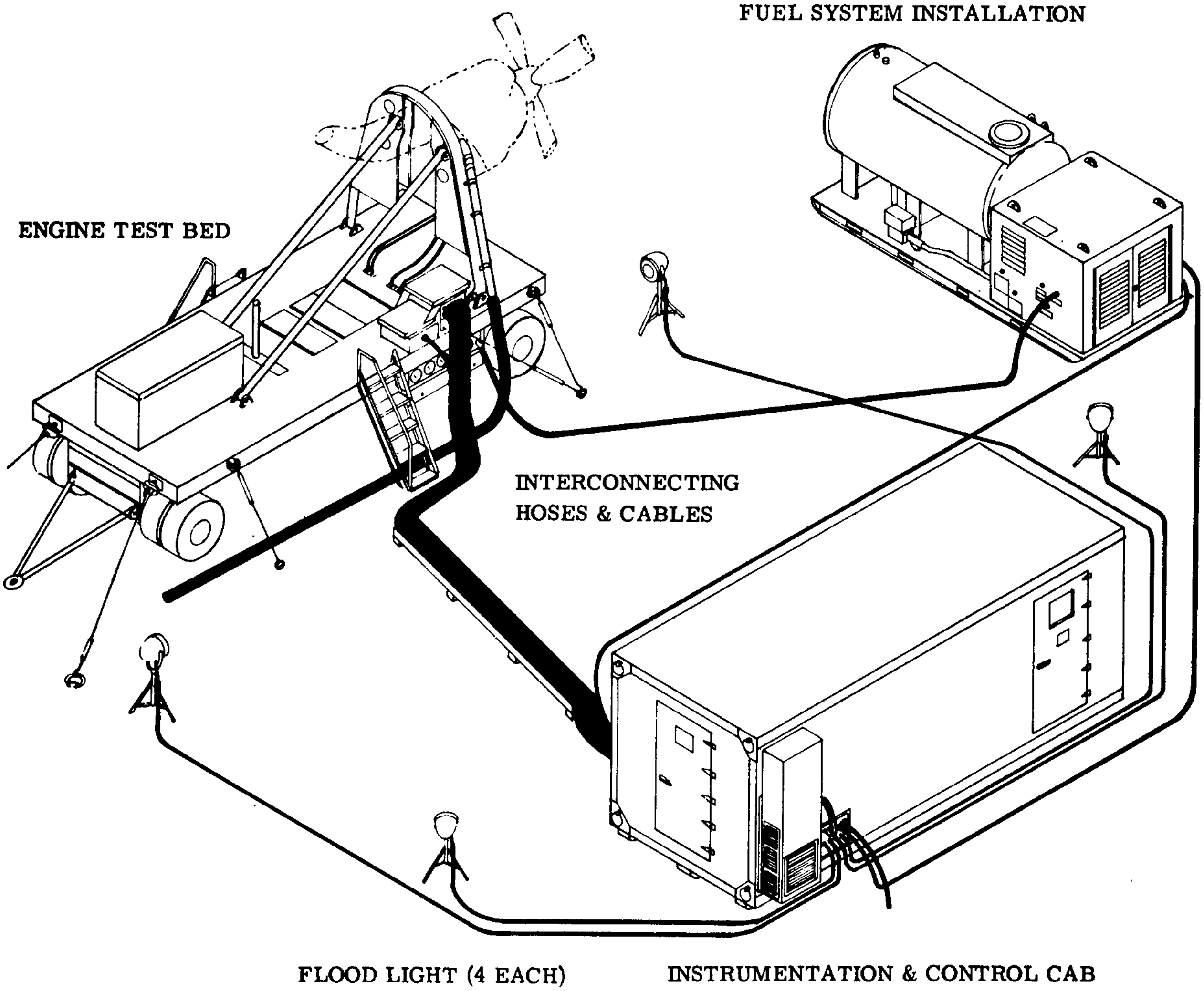

Figure 5-3.—Turboprop engine test system.

needed to satisfactorily conduct functional and performance tests.

The console provides junction facilities to connect the cell power to the engine, a system for remote control measurement of throttle position, a transmitter and receiver to indicate inlet guide vane position, and a dc electronic indicating system for measuring nozzle position. A thermocouple type of anti-icing temperature indicator, a starter circuit, and switches and cables necessary for operation of the engine and console under test conditions are included in some consoles.

ENGINE TEST LOG SHEETS

The engine test log is used to record the data obtained during the engine test run. The log provides a record of the engine test for future reference and acts as documentary proof that the engine was subjected to the prescribed test procedures. The data must be complete, accurate, neat, and legible. Upon receipt of the engine for testing, the operator will enter the name of the testing activity, the engine model, serial number of the engine, and the date of the engine test.

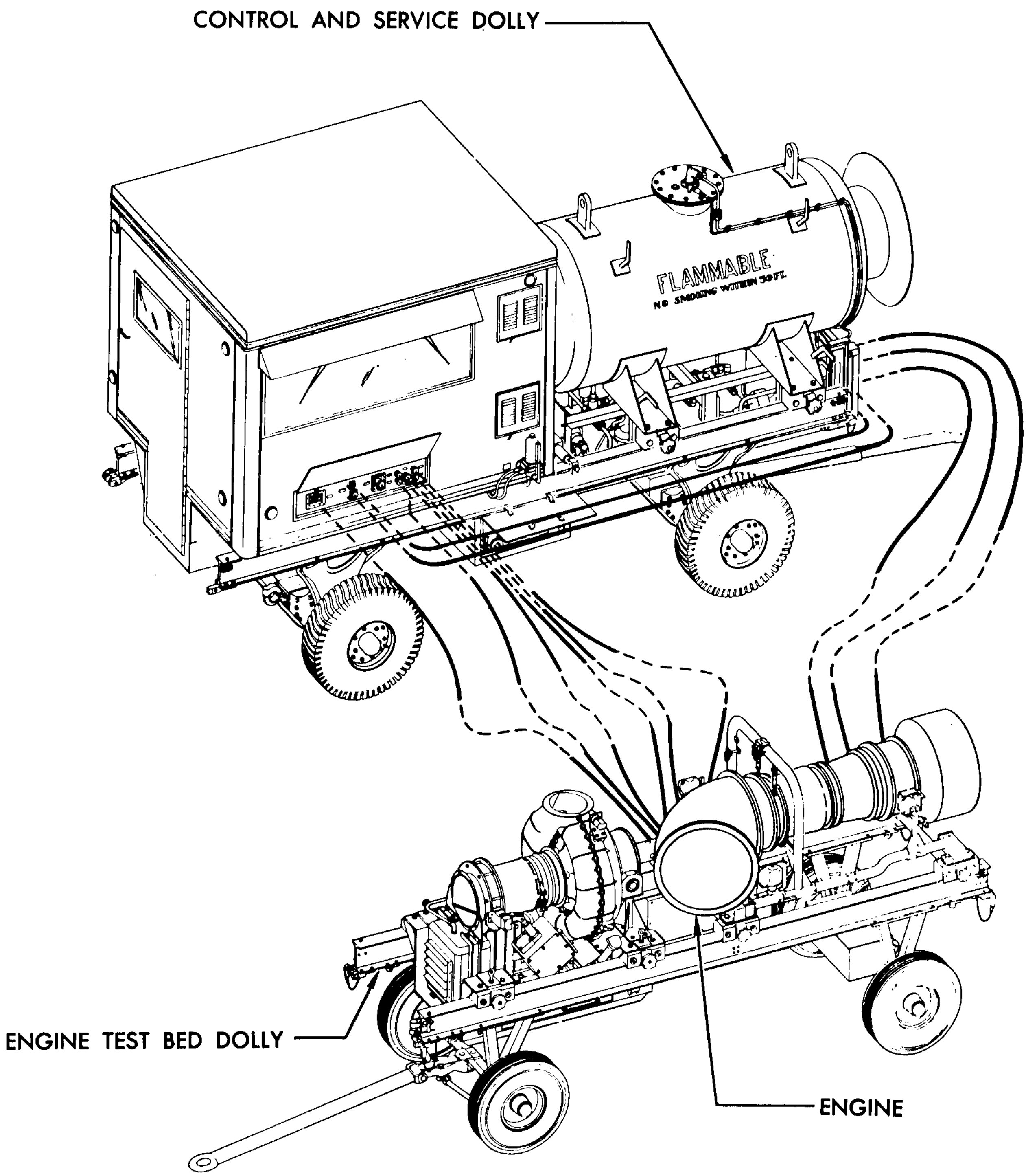

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Figure 5-4.—Engine portable runup test system.

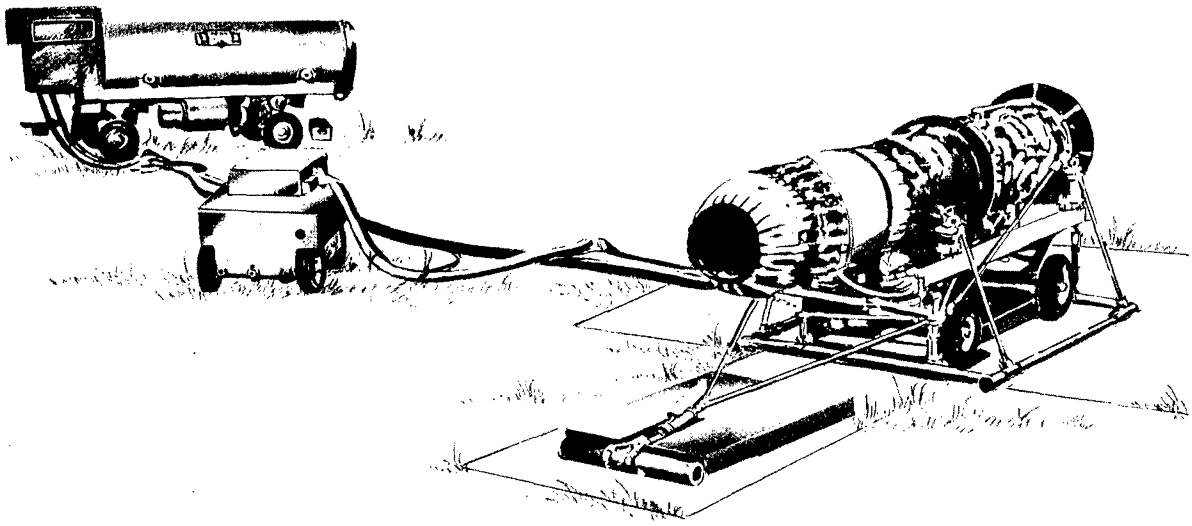

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Figure 5-5.—Engine test and runup system.

During the test, record all unusual occurrences in the remarks section of the test log. Record all starts, shutdowns, times for accelerations, and times for adjustments and settings. During starts, record the time of day the engine was started, maximum turbine inlet temperature encountered, and the duration of that temperature. Record the time for acceleration and the stabilization time.

At the end of the test, record the engine coast-down time. Time is defined as the time elapsed from the moment fuel is cut off to the time the engine comes to a complete stop. Coast-down time has no absolute value. A record maintained for engines will show what the expected average coast-down time should be. Any engine with an abnormally short coast-down time should be viewed with suspicion and investigated for compressor rub or other malfunctions. The operator is required to sign all the test run logs and is held responsible for the accuracy and completeness of all the test data.

Test schedules will vary with each different model of engine and manufacturer. Always refer to the appropriate engine manual when performing engine test runs.

ENGINE OPERATIONS AND CHECKS

Just as starting procedures vary with the various types of engines, the controls and instrumentation vary with different test cells. Checking the engine for proper operation consists primarily of reading engine instruments and then comparing the observed values with those given by the manufacturer for specific engine conditions, atmospheric pressures, and temperatures.

Early model engine test procedures used rpm as the sole engine operating parameter to establish thrust, while many present day engine test procedures use engine pressure ratio (EPR) as the primary thrust indicator. On a hot day, compressor rpm for a given thrust will be higher than on a cold day. A dirty or damaged compressor will reduce thrust for a given rpm. EPR is used because it varies directly with thrust. EPR is the ratio of the total pressure at the front of the compressor to the total pressure at the rear of the turbine. The exhaust gas temperature (EGT) is never used for setting thrust, although it must be monitored to see that the temperature limits are not exceeded. Using EPR as the thrust indicator means that on a hot day it is quite possible for the engine rpm to exceed 100 percent, and on a

cold day, desired thrust ratings may be reached at something less than 100 percent.

TRIMMING

Operational engines must be adjusted occasionally to compensate, within prescribed limits, for thrust deterioration caused by compressor blade deposits of dirt, scale, or other gas path deterioration. This process is called trimming. The word comes from the old practice of adjusting the engine temperature and thrust by cutting or trimming the exhaust nozzle to size. Although the nozzle size on some engines can be varied by the insertion or removal of metal tabs called mice, the trimming process generally involves a fuel-control adjustment to bring the engine to a specific temperature, fuel flow, thrust, and engine pressure ratio. Always follow the prescribed maintenance instructions when performing trimming operations on a specific engine.

When the rated thrust cannot be restored without exceeding other engine limitations, the engine must either be field cleaned or removed and sent to overhaul.

FIELD CLEANING

Field cleaning is accomplished by introducing a lignocellulose material into the air inlet duct while the engine is operating. The cleaning material is made by crushing apricot pits or walnut hulls. Specific steps to follow in cleaning a particular engine are found in the maintenance instructions for the particular engine. These steps generally include blocking some lines and ports and removing any equipment in the inlet duct that might be damaged by the cleaning material. The engine is then run at different speeds for specific periods of time while the cleaning compound is fed into the inlet duct. After cleaning, the installation must be returned to its original configuration and the engine must be retrimmed.

On some engines, cleaning is accomplished by using a washing solution, which consists of an emulsion of demineralized water, kerosene, and other cleaning liquids. Field cleaning of this nature is accomplished as a desalination wash to remove salt deposits when operating in salt-laden air, or as a performance recovery wash to remove dirt and other deposits.

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NONRESIDENT CAREER COURSE

AVIATION MACHINIST'S MATE 1 & C

NAVEDTRA 10324-A

This self-study course is only one part of the total Navy training program. By its very nature it can take you only part of the way to a training goal. Practical experience, schools, selected reading, and YOUR desire to succeed are also necessary to round out a fully meaningful training program.

Your Nonresident Career Course (NRCC) contains a set of assignments and perforated answer sheets. If an errata sheet comes with the NRCC, make all indicated changes or corrections. Do not change or correct the Rate Training Manual (RTM) or assignments in any other way.

HOW TO COMPLETE THIS COURSE SUCCESSFULLY

You should read the RTM before taking the NRCC. Study the RTM pages given at the beginning of each assignment before trying to answer the questions. Pay attention to tables and illustrations as they contain a lot of information. Making your own drawings can help you understand the subject matter. You should read the learning objectives preceding each set of questions. The learning objectives and questions are based on the subject matter of the RTM. The learning objectives tell you what you should be able to do after studying the RTM. Answering the questions should help you accomplish the objectives.

At this point, you should be ready to answer the questions in the assignment. Read each question carefully. Select the BEST ANSWER for each question, consulting your RTM when necessary. Be sure to select the BEST ANSWER from the subject matter in the RTM. You may discuss difficult points in the course with others. However, the answer you select must be your own. Remove a perforated answer sheet from the back of the NRCC, write in the proper assignment number, and enter your answer for each question.

Your NRCC will be administered by your command or, in the case of small commands, by the Naval Education and Training Program Development Center. No matter who administers your course you can complete it successfully by earning a 3.2 for each assignment. The unit breakdown of the course, if any, is shown later under Naval Reserve Retirement Credit.

WHEN YOUR COURSE IS ADMINISTERED BY LOCAL COMMAND

As soon as you have finished an assignment, submit the completed answer sheet to the officer designated to grade it. The graded answer sheet will not be returned to you.

If you are completing this NRCC to become eligible to take the fleetwide advancement examination, follow a schedule that will enable you to complete all assignments in time. Your schedule should call for the completion of at least one assignment per month.

Although you complete the course successfully, the Naval Education and Training Program Development Center will not issue you a letter of satisfactory completion. Your command will make an entry in your service record, giving you credit for your work.

WHEN YOUR COURSE IS ADMINISTERED BY THE NAVAL EDUCATION AND TRAINING PROGRAM DEVELOPMENT CENTER

After finishing an assignment, go on to the next. Retain each completed answer sheet until you finish all the assignments in a unit (or in the course if it is not divided into units). Using the envelopes provided, mail your completed answer sheets to the Naval Education and Training Program Development Center where they will be graded and the score recorded. Make sure all blanks at the top of the answer sheet are filled in. Unless you furnish all the information required, it will be impossible to give you credit for your work. The graded answer sheets will not be returned.

The Naval Education and Training Program Development Center will issue a letter of satisfactory completion to certify successful completion of the course (or a creditable unit of the course). To receive a course-completion letter, follow the directions given on the course-completion form in the back of this NRCC.

You may keep the RTM and assignments for this course. Return them only in the event you disenroll from the course or otherwise fail to complete the course. Directions for returning the RTM and assignments are given on the course disenrollment-course completion form in the back of this NRCC.

PREPARING FOR YOUR ADVANCEMENT EXAMINATION

The *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards*, NAVPERS 18068, lists by paygrade the minimum tasks you must be able to perform in your rating. These tasks are called occupational standards. Your examination for advancement is based on these occupational standards. The material used to prepare the questions for your advancement examination is listed in the *Bibliography for Advancement Examination Study*, NAVEDTRA 10052. For your convenience, the occupational standards and the bibliography for your rating are combined in a single booklet for the examinations given each year. These *Occupational Standards and Bibliography* booklets are available from your Educational Services Officer (ESO). Even though you have met the course requirement by successfully completing this NRCC, you should continue to study the RTM as you prepare for the advancement examination. Remember the RTM is one of the sources for advancement examination questions. Because the qualifications for your rating may have changed since your RTM was printed, you should refer to the latest annual edition of the rating *Occupational Standards and Bibliography* booklet.

NAVAL RESERVE RETIREMENT CREDIT

This course is evaluated at 6 Naval Reserve retirement points. Points will be credited upon satisfactory completion of the assignments 1 through 4. These points are creditable to personnel eligible to receive them under current directives governing retirement of Naval Reserve personnel.

COURSE OBJECTIVE

In completing this NRCC, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following: Fuel System Maintenance, Power Plant Troubleshooting, Power Plant Repair, Propeller Maintenance and Jet Engine Testing and Operation.

While working on this correspondence course, you may refer freely to the text. You may seek advice and instruction from others on problems arising in the course, but the solutions submitted must be the result of your own work and decisions. You are prohibited from referring to or copying the solutions of others, or giving completed solutions to anyone else taking the same course.

Naval courses may include several types of questions—multiple-choice, true-false, matching, etc. The questions are not grouped by type but by subject matter. They are presented in the same general sequence as the textbook material upon which they are based. This presentation is designed to preserve continuity of thought, permitting step-by-step development of ideas. Not all courses use all of the types of questions available. The student can readily identify the type of each question, and the action required, by inspection of the samples given below.

MULTIPLE-CHOICE QUESTIONS

Each question contains several alternatives, one of which provides the best answer to the question. Select the best alternative, and blacken the appropriate box on the answer sheet.

SAMPLE

s-1. Who was the first person appointed Secretary of Defense under the National Security Act of 1947?

1. George Marshall
2. James Forrestal
3. Chester Nimitz
4. William Halsey

Indicate in this way on the answer sheet:

	1 T	2 F	3	4	
s-1	□	■	□	□	_ _ _

TRUE-FALSE QUESTIONS

Mark each statement true or false as indicated below. If any part of the statement is false the statement is to be considered false. Make the decision, and blacken the appropriate box on the answer sheet.

SAMPLE

s-2. All naval officers are authorized to correspond officially with any systems command of the Department of the Navy without their respective commanding officer's endorsement.

1. True
2. False

Indicate in this way on the answer sheet:

	1 T	2 F	3	4	
s-2	□	■	□	□	_ _ _

MATCHING QUESTIONS

Each set of questions consists of two columns, each listing words, phrases or sentences. The task is to select the item in column B which is the best match for the item in column A that is being considered. Items in column B may be used once, more than once, or not at all. Specific instructions are given with each set of questions. Select the numbers identifying the answers and blacken the appropriate boxes on the answer sheet.

SAMPLE

In questions s-3 through s-6, match the name of the shipboard officer in column A by selecting from column B the name of the department in which the officer functions. Some responses may be used once, more than once, or not at all.

A. OFFICER	B. DEPARTMENT
s-3. Damage Control Assistant	1. Operations Department
s-4. CIC Officer	2. Engineering Department
s-5. Disbursing Officer	3. Supply Department
s-6. Communications Officer	

Indicate in this way on the answer sheet:

	1 T	2 F	3	4	
s-3	□	■	□	□	_ _ _
s-4	■	□	□	□	_ _ _
s-5	□	□	■	□	_ _ _
s-6	■	□	□	□	_ _ _

Assignment 1

Textbook Assignment: "Fuel System Maintenance; Power Plant Troubleshooting." Pages 1-1 through 2-5

In this course you will demonstrate that learning has taken place by correctly answering training items. The mere physical act of indicating a choice on an answer sheet is not in itself important; it is the mental achievement, in whatever form it may take, prior to the physical act that is important and toward which course learning objectives are directed. The selection of the correct choice for a course training item indicates that you have fulfilled, at least in part, the stated objective(s).

The accomplishment of certain objectives, for example, a physical act such as drafting a memo, cannot readily be determined by means of objective type course items; however, you can demonstrate by means of answers to training items that you have acquired the requisite knowledge to perform the physical act. The accomplishment of certain other learning objectives, for example, the mental acts of comparing, recognizing, evaluating, choosing, selecting, etc., may be readily demonstrated in a course by indicating the correct answers to training items.

The comprehensive objective for this course has already been given. It states the purpose of the course in terms of what you will be able to do as you complete the course.

The detailed objectives in each assignment state what you should accomplish as you progress through the course. They may appear singly or in clusters of closely related objectives, as appropriate; they are followed by items which will enable you to indicate your accomplishment.

All objectives in this course are learning objectives and items are teaching items. They point out important things, they assist in learning, and they should enable you to do a better job for the Navy.

This self-study course is only one part of the total Navy training program; by its very nature it can take you only part of the way to a training goal. Practical experience, schools, selected reading, and the desire to accomplish are also necessary to round out a fully meaningful training program.

Learning Objective: Recognize the F/A-18 fuel system and identify the engine and external fuel systems operations.

1-1. All of the aircraft fuel tanks can be refueled on the ground through what type refueling point?

1. Single pressure
2. Dual pressure
3. Single gravity feed
4. Dual gravity feed

1-2. Which of the following types of valve is used to control the fuel level of all tanks during refueling?

1. One-way check valve
2. Pressure relief valve
3. Float type valve
4. Gate valve

1-3. What two tanks in the wing tank system are the fuel transfer tanks?

1. Tanks 1 and 4
2. Tanks 1 and 3
3. Tanks 2 and 4
4. Tanks 2 and 3

1-4. The fuel in the internal wing transfer tanks will continue to transfer even if the fuel transfer pumps fail. This transfer is caused by what presure on the fuel?

1. Engine bleed air pressure
2. Outside ram air pressure
3. Pressure due to motive flow
4. Pressure due to gravity

1-5. Positive pressure is maintained on all internal fuel tanks and provision made for fuel transfer from the external fuel tanks by what means?

1. By motive flow
2. By outside ram air
3. By engine bleed air
4. By pump pressure flow

1-6. What devices are used to control the fuel level in the engine feed tanks?

1. Fuel level sensors
2. Fuel level floats
3. One-way check valves
4. Gate valves

1-7. Aircraft fuel can NOT be dumped overboard from which of the following tanks?

1. Wing tanks
2. Engine feed tanks
3. External tanks
4. Transfer tanks

1-8. For safety reasons, internal fuel tanks are located in what area?

1. Aft of the engines
2. Parallel to the engines
3. Forward of the engines
4. Below the engines

1-9. What portion(s) of the engine fuel feed tanks is/are self-sealing?

1. Upper portion only
2. Lower portion only
3. Sides only
4. Entire tank

1-10. During a rapid descent, venting of the fuel tanks prevents stretching of the fuel tanks.

1. True
2. False

1-11. Fuel is supplied to each engine by what total number of fuel pumps?

1. One
2. Two
3. Three
4. Four

1-12. What fuel tank feeds the left engine?

1. No. 1
2. No. 2
3. No. 3
4. No. 4

1-13. In each of the engine fuel feed tanks is an inverted flight fuel compartment that allows for what maximum number of seconds of inverted flight?

1. 10 seconds
2. 15 seconds
3. 20 seconds
4. 25 seconds

1-14. Fuel is transferred from the external fuel tanks by what method?

1. Static air flow
2. Electric transfer pumps
3. Motive flow from engine pumps
4. Engine bleed air

Learning Objective: Identify the operation of the Maintenance Status Display and Recording System (MSDRS).

1-15. The maintenance status display and recording system (MSDRS) receives input from the fuel system and sends data to what computer system?

1. Fuel totalizer and density computer system
2. On board mission computer system
3. Ground control fuel management system
4. Integrated fuel function and discrepancy system

1-16. When the computer system detects a fuel system failure or malfunction, an applicable maintenance code is sent to the MSDRS digital display indicator located in the

1. nosewheel well
2. left main landing gear well
3. transceiver section electronics bay
4. air refueling and low-pressure fire extinguishing bay

1-17. The MSDRS will display and record fuel system malfunctions which may be read and interpreted by the mechanic as an aid to fuel system troubleshooting.

1. True
2. False

Learning Objective: Identify the types of fuel tank construction.

1-18. Fuel tank construction depends upon which of the following factors?

1. Materials available
2. Type of aircraft mission
3. Type of aircraft
4. Both 2 and 3 above

1-19. What material produces the self-sealing action in the self-sealing fuel tanks?

1. Sealant in contact with petroleum
2. Neoprene in contact with sealant
3. Selant between layers of nylon
4. Neoprene in the standard six ply cells

1-20. The most common self-sealing fuel cell is of what type?

1. Combination bladder and self-sealing cell
2. Construction standard cell
3. Neoprene cell
4. Nylon cell

1-21. Self-sealing cells contain what total number of primary layers of material?

1. One
2. Two
3. Three
4. Four

1-22. The inner liner of the self-sealing fuel cell is made from what material?

1. Neoprene
2. Natural rubber
3. Nylon impregnated plastic
4. Nitrile coat nylon fabric

1-23. The retainer material used in self-sealing fuel cell construction is used for what purpose?

1. To make the cell more pliable
2. To repel bullet penetration
3. To add strength and support to the cell
4. To make the cell easier to remove

1-24. The retainer material used in self-sealing fuel cell construction is made from what material?

1. Neoprene
2. Nylon cord fabric
3. Natural rubber
4. Buna N impregnated plastic

Learning Objective: Recognize fuel systems maintenance practices and procedures.

1-25. Flapper valves are fitted to some baffles inside a fuel tank to prevent

1. fuel sloshing
2. fuel flow in two directions
3. cell distortion during rapid altitude changes
4. cell dryness during extended aircraft storage

1-26. What are the advantages of the bladder-type fuel cell as compared to the self-sealing fuel cell?

1. Weight and puncture resistance
2. Cost and puncture resistance
3. Cost and ease of handling
4. Weight, cost and ease of repair

1-27. Bladder-type fuel cells are farbricated to a size that is slightly

1. smaller than the self-sealing fuel tank
2. slightly larger than the aircraft's cavity
3. the same size as the aircraft's cavity
4. the same size as a self-sealing fuel tank

1-28. What is the trade name stenciled on the outside of a nylon-type bladder cell?

1. Goodyear
2. Goodrich
3. Pliocel
4. Buna N

1-29. When you find conflicting information between the specific fuel system portion of the aircraft maintenance manual and the Aircraft Fuel Cell and Internal/External Tank manual (NA 01-1A-35), what rule must you follow?

1. The manual that has the latest date has precedance
2. The NA 01-1A-35 has precedence for cargo-type aircraft
3. The aircraft maintenance manual has precedence over the NA 01-1A-35
4. The NA 01-1A-35 has precedence over the aircraft maintenance manual

1-30. A very small percentage of fuel vapors can cause serious physical problems to personnel working in the fuel cell area. Fuel vapors are heaviest in what part of empty cells?

1. Lower area of the cells only
2. Fuel baffle and internal bulkhead areas
3. Internal side walls of bladder-type and self-sealing cells
4. Upper and lower areas of the cells

IN ANSWERING QUESTIONS 1-31 THROUGH 1-33, SELECT FROM COLUMN B THE TERM THAT RELATES TO THE PROCESS LISTED IN COLUMN A. SOME RESPONSES WILL NOT BE USED.

	A. Processes	B. Terms
1-31.	Removing residual fuel from cells after defueling	1. Defueling
		2. Depuddling
1-32.	Transferring fuel from the aircraft cell into mobile, portable, or fixed tanks	3. Inerting
		4. Purging
1-33.	Removing inert vapors, fuel vapors or any other vapor capable of producing a combustible or toxic atmosphere	

1-34. When purging an aircraft the area surrounding it must be roped off from all other aircraft a minimum of how many feet?

1. 100 feet
2. 75 feet
3. 50 feet
4. 25 feet

1-35. All radio and radar equipment must be turned off if they are within what maximum distance of an aircraft being defueled?

1. 50 feet
2. 100 feet
3. 150 feet
4. 200 feet

1-36. Before defueling an aircraft, you must ensure that engines are not being operated within what minimum distance from your aircraft?

1. 100 feet
2. 200 feet
3. 300 feet
4. 400 feet

1-37. What type of maintenance, if any, is permitted during an aircraft defueling operation?

1. Routine maintenance which does not require electrical power
2. Special inspections which do not require gas turbine support equipment operation
3. Landing gear maintenance which does not require retraction checks
4. None

1-38. Which of the following is NOT a recognized method of purging a fuel cell?

1. Air blow
2. Air exhaust
3. Water injection
4. Oil purge

1-39. What are two approved methods of inerting a fuel cell?

1. Hot and cold
2. Siphon and pressure
3. Wet and dry
4. Depuddling and purging

1-40. What agent is used for inerting a fuel cell?

1. Water
2. Hydrogen
3. Inert gas
4. Air

1-41. What is the major cause of fuel leaks in newly installed fuel cells?

1. Incorrect size cell installed
2. Incorrect maintenance procedures
3. Use of improper sealing compound
4. Installation of damaged cells

1-42. Dripping leaks are found at fuel system plumbing connections. Leaks are generally caused by which of the following actions?

1. Overtorquing lines
2. Under or overtorquing hoses
3. Undertorquing fittings
4. Each of the above

1-43. When you are using colored dye in leak source analysis, what is the proper ratio of dye to fuel?

1. 2 ounces of dye to 100 gallons of fuel
2. 2 ounces of dye to 150 gallons of fuel
3. 3 ounces of dye to 100 gallons of fuel
4. 3 ounces of dye to 150 gallons of fuel

1-44. When using colored dye in fuel systems to detect "hidden" fuel leaks, you should use which of the following procedures?

1. Always add fuel to the dye
2. Always add dye to the fuel
3. Never add mixed dye to empty fuel systems
4. Never use dye when checking areas near the engine hot section

1-45. When handling fuel cells, which of the following safety precautions should you observe?

1. Never use fuel cell fittings for hand holds during carrying
2. Never drag or roll the cell on the deck
3. Always place a protective barrier under the cell when placing on the deck
4. All of the above

1-46. To prevent damage to a self-sealing fuel cell, you should never leave the cell in a collapsed condition for more than what maximum period of time?

1. 1 hour
2. 2 hours
3. 3 hours
4. 4 hours

1-47. A bladder-type fuel cell (providing it is adequately protected) may be left collapsed for what maximum period of time?

1. 1 hour
2. 1 day
3. 1 week
4. Indefinitely

1-48. When a fuel cell maintenance time exceeds 72 hours, the cell interior walls must be coated with which of the following oils?

1. Mineral oil
2. Vegetable oil
3. Grade 1010 oil
4. Grade 1100 oil

1-49. Pliocel-type bladder cells require no internal preservation as long as storage does not exceed what maximum period of time?

1. 1 week
2. 2 weeks
3. 3 weeks
4. 4 weeks

1-50. Fuel cells that are to remain in storage for long periods of time should be coated with which of the following oils?

1. Grade 1010 oil
2. Grade 1100 oil
3. Grade 1065 oil
4. Grade 1165 oil

Learning Objective: Identify factors to be considered in establishing a safe and efficient engine maintenance program.

1-51. Troubleshooting aircraft engines is defined as

1. the ability to interpret troubleshooting charts and graphs
2. the reduction of the maintenance effort through correct engine maintenance
3. the systematic and thorough analysis of the symptoms of engine malfunctions
4. the skills developed through adherence to current directives pertaining to engine operations

1-52. Which of the following requirements is essential for you to troubleshoot an aircraft engine properly?

1. Support from AIMD personnel
2. Complete set of engine tools
3. Formal training on the engine
4. A thorough knowledge of the engine

1-53. Which of the following characteristics describes the most efficient maintenance program?

1. All components are changed at prescribed intervals
2. Malfunctions are detected before trouble arises
3. Maintenance actions between phase inspections are kept at a minimum
4. The symptoms of malfunctions are corrected

1-54. In addition to correcting an engine trouble and restoring it to its normal operating condition, you, as the troubleshooter, should take which of the following actions?

1. Use the obvious corrected fix
2. Trace an abnormal indication to it's source
3. Rely on a single source for indication
4. Accept the instrument reading as being correct

1-55. What is the most common cause of repeat engine discrepancies?

1. Use of faulty maintenance equipment
2. Poor troubleshooting procedures
3. Inadequate time for maintenance
4. Lack of information on use of maintenance equipment

1-56. Troubleshooting aids, for the seven steps involved in good deductive troubleshooting are found in which of the following publications?

1. NATOPS flight manuals
2. Jet engine accident reports
3. General information reports
4. Maintenance instructions manuals

1-57. Troubleshooting charts contain information pertaining to

1. troubles, possible causes, and suggested remedies to correct the troubles
2. publications of aircraft and engine discrepancies
3. problems encountered during phase maintenance
4. repeat engine discrepancies

1-58. What is your primary responsibility as a senior AD petty officer?

1. To perform maintenance tasks
2. To train inexperienced personnel on the job
3. To supervise and instruct subordinates in aircraft maintenance
4. To establish standards and quality for aircraft maintenance

1-59. As a supervisor, you must be constantly aware of which of the following conditions?

1. Workload capability of all supporting shops
2. Workers readiness and physical ability to perform quality work
3. Demands of an existing flight schedule
4. Degree and frequency of maintenance discrepancies

1-60. Discovery and elimination of unsafe work practices in aircraft maintenance is the responsibility of which of the following personnel?

1. The shop supervisor
2. The squadron safety officer
3. The aircraft maintenance officer
4. All of the above

Assignment 2

Textbook Assignment: "Power Plant Troubleshooting; Power Plant Repair." Pages 2-5 through 3-14

Learning Objective: Recognize power plant troubleshooting safety practices.

2-1. When you are working on a jet aircraft with the engine operating, take extreme caution to avoid which of the following areas?

1. Wheel well
2. Wing tip
3. Air intake
4. Flap area

2-2. If maintenance is required on an engine equipped with auxiliary air doors, which of the following safety precautions should you observe?

1. Insure auxiliary power is available for air doors operation
2. Connect low aircraft power to the air doors actuators
3. Place only necessary tools between the air doors and maintenance personnel
4. Install a jury strut or disconnect the air door operating mechanism

2-3. After jet engine shutdown, you should not work in or inspect the exhaust area for what minimum period of time?

1. 1 hour
2. 2 hours
3. 30 minutes
4. 45 minutes

2-4. You should always allow for a sufficient period of time between the operation of the ignition system and the checking of ignition components for which of the following reasons?

1. To prevent in accurate voltage readings due to heat
2. To prevent incorrect continuity readings due to residual voltages
3. To provide for correct readings on the ignition analyzer
4. To provide time for dissipation of electrical energy

2-5. Short exposure to extremely high levels of noise may result in damage to the eardrums. Ear protection must be used when you are exposed to what minimum decibel (dB) level?

1. 10 dB
2. 90 dB
3. 180 dB
4. 400 dB

2-6. Noise can affect your ear mechanism in such a manner as to cause which of the following physical problems?

1. Unsteadiness only
2. Inability to walk only
3. Inability to stand only
4. Unsteadiness and the inability to walk or stand

Learning Objective: Recognize the power plant troubleshooting practices and procedures.

2-7. When isolating and correcting engine discrepancies what is the best procedure to follow?

1. Begin with the least likely cause
2. Being with the most obvious cause
3. Proceed systematically through all systems
4. Proceed randomly through all systems

2-8. The basic turbojet engine is composed of what total number of sections?

1. One
2. Two
3. Three
4. Four

2-9. What section of the engine is most susceptible to foreign object damage (FOD)?

1. Afterburner section
2. Combustion section
3. Accessory section
4. Compressor section

● Refer to Tables 2-1 through 2-8 in answering questions 2-10 through 2-16.

2-10. When the compressor fails to rotate during an attempted start which of the following troubles is the cause?

1. No fuel to engine
2. Low air supply to engine
3. Inadequate air supply to starter
4. Defective ignition system

2-11. Which of the following troubles is NOT a probable cause of an engine hot start?

1. Defective ignition
2. Insufficient cranking speed
3. Accumulation of fuel in the engine
4. Open thermocouple leads

2-12. Afterburning does not take place when the throttle is placed in the afterburner position. You have investigated and isolated the problem to a defective solenoid on the afterburner fuel control. What should you do to correct the discrepancy?

1. Replace the linkage
2. Replace the afterburner igniter
3. Replace the afterburner switch
4. Replace the afterburner fuel control

IN ANSWERING QUESTIONS 2-13 THROUGH 2-15, SELECT FROM COLUMN B THE CAUSE THAT BEST FITS THE DISCREPANCY LISTED IN COLUMN A. (SEE TABLE 2-8.) NOT ALL RESPONSES IN COLUMN B ARE USED.

	A. Discrepancies	B. Causes
2-13.	High oil temperature	1. Malfunctioning breather pressurizing valve
2-14.	Low oil temperature	2. Bearing failure
2-15.	Fluctuating oil pressure	3. Thermostatic valve malfunction (fuel coolant oil cooler)
		4. Relief valve adjustment backed off

2-16. which of the following is a cause for excessive oil consumption?

1. Breather pressurizing valve not functioning properly
2. Main oil pump malfunction
3. Oil pressure relief valve malfunctioning
4. Misadjusted relief valve

Learning Objective: Identify function and operation of the Navy Oil Analysis Program (NOAP).

2-17. An engine may be retained in service after metal particles are found in the oil system based on which of the following considerations?

1. Kind of metal
2. Quantity of metal
3. Source of metal
4. All of the above

IN ANSWERING QUESTIONS 2-18 THROUGH 2-20, SELECT FROM COLUMN B THE EQUIPMENT OR CHEMICAL RECOMMENDED FOR USE IN IDENTIFING METAL PARTICLES FOUND IN ENGINE SYSTEMS LISTED IN COLUMN A. NOT ALL RESPONSES IN COLUMN B ARE USED.

	A. Metal Particles	B. Equipment/ Chemicals
2-18.	Copper	1. Permanent magnet
2-19.	Steel	2. Soldering iron
2-20.	Tin	3. Hydrochloric acid
		4. Nitric acid

2-21. A silver particle dropped in nitric acid produces what reaction?

1. A bluish green cloud
2. Rapid dissolution of the particle
3. A whitish fog
4. A purple cloud

2-22. All activities operating aeronautical equipment are required to participate in the Navy Oil Analysis Program. Which of the following people/activites have the authority to relieve them from this requirement?

1. Squadron commanding officer
2. Squadron maintenance officer
3. Cognizant field activity (CFA)
4. Local rework activity

2-23. Wear metals are generated by the relative motion between metallic parts in moving contact in an unlubricated mechanical system.

1. True
2. False

2-24. For normally operating equipment, wear is produced at what rate?

1. Constant rate
2. High rate after initial break-in
3. Varying rate after initial break-in
4. Low rate during initial break-in

2-25. During initial break-in, new or newly overhauled engine assemblies tend to produce which of the following concentrations of wear metals?

1. Exceptionally low
2. Low
3. Exceptionally high
4. High

2-26. What is the total number of methods of spectrometic oil analysis?

1. One
2. Two
3. Three
4. Four

2-27. The atomic absorption spectrometer measures wear metals in lubricating fluids by subjecting the fluid to what energy source?

1. High-velocity air flow
2. High-temperature flame
3. High-energy light
4. High-voltage spark

2-28. Spectrometric fluid analysis is effective only for those failures which are characterized by a normal increase in the wear metal content of the lubricating fluid.

1. True
2. False

2-29. A sudden increase of wear metals in one component and a decrease in another component should be considered a problem related to

1. mislabeling of the samples
2. catastrophic failure of both components
3. improper sampling of both components
4. faulty spectrometric analysis

2-30. Oil sampling intervals should not vary from that specified for a given type/model/series of equipment by more than what prescribed amount?

1. $\pm$ 5 percent
2. $\pm$ 10 percent
3. $\pm$ 15 percent
4. $\pm$ 20 percent

2-31. Which of the following is NOT considered a routine sample under the oil analysis program?

1. Samples requested by the CFA
2. Samples taken prior to the replacement of a major oil lubricating component
3. Samples taken after the replacement of a major oil lubricating component
4. Each of the above

2-32. The two basic methods of taking a fluid sample are the dip tube technique and the

1. suction/pressure technique
2. cold flow technique
3. drain technique
4. accumulated sediment technique

2-33. Which of the following publications provides complete information on the Navy Oil Analysis Program?

1. OPNAVINST 4731.1 (Series)
2. OPNAVINST 4790.2 (Series)
3. NAVMATINST 4731.1 (Series)
4. NAVMATINST 4790.2 (Series)

Learning Objective: Identify the allowable repair limits at the local and intermediate levels for different jet engine sections.

2-34. What is the primary purpose of an intermediate maintenance activity?

1. To support and supplement the work of organizational maintenance activities
2. To support and supplement the work of depot level maintenance activities
3. To support all shore based maintenace activities
4. To supplement all carrier-based maintenance activities

IN ANSWERING QUESTIONS 2-35 AND 2-36, SELECT FROM COLUMN B THE STATEMENT WHICH DESCRIBES THE DEGREE OF REPAIR LISTED IN COLUMN A. NOT ALL RESPONSES IN COLUMN B ARE USED.

	A. Degree of Repair	B. Statements
2-35.	First Degree Repair	1. Repair that consists of major engine inspections
2-36.	Second Degree Repair	2. Repair that includes compressor rotor replacement
		3. Repair that includes the repair or replacement of turbine rotors, gearboxes and accessories

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2-37. Under the Gas Turbine Maintenance Program, the third-degree repair category, EXCLUDES which of the following functions?

1. Those requiring low maintenance man-hours
2. Those with a high incidence rate
3. Those requiring high maintenance man-hours
4. Those with a moderate incidence rate

2-38. What degree of gas turbine engine repair, if any, is the same as complete engine repair (CER)?

1. First Degree
2. Second Degree
3. Third Degree
4. None

2-39. As established by OPNAVINST 4790.2 (Series), all aircraft maintenance is to be accomplished at what level of maintenance?

1. The highest level of maintenance
2. The lowest level of maintenance
3. The assigned level of maintenance
4. The closest AIMD level of maintenance

2-40. What is the most important consideration for the successful inspection of an aircraft component that has been sent in for repair?

1. The type of component
2. The aircraft model
3. The cleaning of the component
4. The type of inspection

2-41. Emulsion cleaners should be used to clean an engine or component prior to inspection for which of the following reasons?

1. They are neutral and noncorrosive
2. They are inexpensive as compared to other cleaners
3. They remove baked on grease better than other cleaners
4. They are all-purpose cleaners suitable for both plastic and metal parts

2-42. Welding of jet engine parts is never permissable.

1. True
2. False

2-43. Nuts and bolts used in the hot section of an engine are normally of what type?

1. Same type as used throughout the engine
2. Special heat resistant material
3. Copper engine or lead residue resistant
4. Low coefficient of expansion and/or contraction

2-44. Marking of hot section components that are directly exposed to the gas path may be accomplished using which of the following items?

1. Lead pencil
2. Spray paint
3. Etch mark
4. Layout dye

2-45. Any temporary marking method that you use which leaves a heavy carbon deposit on hot section components may cause which of the following types of corrosion?

1. Stress
2. Intergranular
3. Fretting
4. Pitting

2-46. What portion of a compressor blade leading edge may be reworked with a file?

1. The upper 3/4
2. The upper 2/3
3. The lower 3/4
4. The lower 2/3

2-47. What portion of a compressor blade dimension must remain basically unchanged when reworking any minor nicks?

1. The upper 1/3
2. The lower 1/3
3. The upper 1/2
4. The lower 1/2

2-48. You must inspect all compressor blades for cracks after reworking by what type of inspection?

1. Visual
2. Dye penetrant
3. Magnaflux
4. X-ray

2-49. When a complete replacement of the entire compressor case is accomplished, it is also necessary for you to replace the compressor rotor.

1. True
2. False

2-50. When, if ever, is the straightening of folded compressor vanes permissible?

1. When the fold does not exceed 1/8 inch
2. When the vane is straightened without buckling
3. When the straightened vane passes a dye penetrant inspection check
4. Never

2-51. When blending compressor vanes, you should use which of the following procedures?

1. Grind/file the blade from side to side
2. Grind/file the blade lengthwise
3. Grind diagonally across the blade
4. File in a circular motion on the blade

2-52. A combustion liner that is found to have a buckled area in excess of 3/16 of an inch wave is made serviceable by which, if any, of the following methods?

1. Straightening
2. Blending
3. Brazing
4. None of the above

2-53. Combustion chamber liners may be retained in service when which of the following conditions are present?

1. Cracks less than 0.125 inches long emanate from a combustion air hole
2. No more than three cracks emanate from a combustion section hole
3. Radial/circumferential cracks of less than 0.750 inches long emanate from crossover tubes
4. All of the above

2-54. Combustion liners that show evidence of burning have what maintenance status?

1. They are reusable, if other liner defects are within repair limits
2. They are reusable, only if no other liner defects are found
3. They are reusable, only if the deflectors are not cracked
4. They are not reusable

2-55. What is the maximum number of cooling louver tabs that may be totally burned and still be within acceptable limits?

1. One
2. Two
3. Three
4. Four

2-56. Which of the following conditions is considered serious when the turbine rotor is sulfidated?

1. Splitting
2. Delamination
3. Flaking
4. All of the above

2-57. Splined drive shafts that are connected to engine rotor shafts must be carefully removed or installed to prevent spline damage. Most mating gears require backlash as well as which of the following checks?

1. Elasticity check
2. Clearance check
3. Hardness and local stress checks
4. Tooth-to-tooth contact area check

Assignment 3

Textbook Assignment: "Propeller Maintenance." Pages 4-1 through 4-18.

Learning Objective: Recognize a propeller system and identify the assemblies and components.

3-1. Which of the following aircraft use the 54H60 series propeller?

1. C-130
2. E-2
3. P-3
4. All the above

3-2. What is the primary function of a propeller system?

1. To increase engine rpm
2. To increase or decrease pitch as required by power lever movement
3. To reduce the propeller drive shaft speed
4. To reduce engine rpm

3-3. The propeller assembly is comprised of what total number of major sub-assemblies?

1. Six
2. Five
3. Three
4. Four

3-4. The feather blade angle is set at what degree?

1. -14.5°
2. -86.65°
3. +86.65°
4. +14.50°

3-5. During what range of operation does the propeller maintain a constant rpm of 100 percent?

1. Delta range
2. Charley range
3. Beta range
4. Alpha range

3-6. From the flight idle blade angle to the reverse blade angle is called what range of operation?

1. Delta range
2. Alpha range
3. Charley range
4. Beta range

3-7. In what range of operation is negative thrust provided?

1. Charley range
2. Beta range
3. Delta range
4. Alpha range

3-8. Propeller system design changed when propellers were adapted to jet engines for what reason?

1. The increase in jet engine rpm
2. The location of propeller mounting on the engine
3. The reduction in propeller drive shaft speeds
4. The necessity for rapid power change

3-9. The propeller blades are retained by what assembly?

1. Pitchlock assembly
2. Barrel assembly
3. Low pitch stop assembly
4. Dome assembly

Learning Objective: Identify propeller components, their purpose, functions and operating features.

3-10. What component(s) of the barrel assembly is/are kept together throughout the service life of the propeller?

1. Propeller hub nut
2. Front and rear cones
3. Front and rear barrel sections
4. Internally relieved stud extensions (barrel bolts)

3-11. Which of the following barrel components carry the high centrifugal blade loads?

1. Beta segment gears
2. Split thrust washers
3. Barrel shoulders and lips
4. Blade segment gears

3-12. The barrel assembly contains what total number of cone types?

1. One
2. Two
3. Three
4. Four

3-13. The beta segment gear is located on what propeller blade?

1. Number 1 blade
2. Number 2 blade
3. Number 3 blade
4. Number 4 blade

3-14. The 54H60-77 propeller blades are forged from what material(s)?

1. Fiberglass
2. Solid steel alloy only
3. Solid aluminum alloy only
4. Steel/aluminum alloy

3-15. The propeller blade butt is partially hollow for which of the following reasons?

1. Installation of the blade balancing assembly
2. Weight control
3. Increased blade strength
4. Installation of blade deicer elements

3-16. The blade heater assembly is bonded to what part of the blade?

1. The trailing edge of the blade fairing
2. The blade tip
3. The leading edge of the blade fairing
4. The blade shank

3-17. What condition requires blade heater assembly replacement?

1. A scheduled component removal time
2. When more than four wires of the heater assembly are damaged
3. When the nylon reinforced neoprene cover material shows signs of weather corrosion
4. When FOD strikes the blade

3-18. What is the purpose of the blade cuff?

1. To reduce weight of the blade
2. To provide mounting for the heater assembly
3. To direct airflow around the dome assembly for cooling
4. To direct airflow to the engine intake

3-19. What is the blade angle changing mechanism of the propeller system called?

1. The blade assembly
2. The dome assembly
3. The barrel assembly
4. The propeller control assembly

Learning Objective: Identify assembly/disassembly procedures involved in propeller repair.

3-20. The propeller stationary and rotating cams are a part of what assembly?

1. The barrel assembly
2. The control assembly
3. The dome assembly
4. The low pitch stop lever assembly

3-21. When assembling the 54H60-77 propeller dome, what bearings are installed by hand?

1. Outboard cam bearings
2. Front cone bearings
3. Rear cone bearings
4. Inboard ball bearings

3-22. In the propeller assembly, the inboard and outboard movement of the piston is used to change the blade angle by what means?

1. By transmitting movement from the rotating cam directly to the blade segmental gears
2. By converting movement to oil pressure which is transmitted to the blades segmental gears
3. By transmitting movement to the stationary cams
4. By transmitting movement through the control assembly

3-23. What unit(s) separate(s) the inboard and outboard hydraulic pressure in the dome/piston assembly?

1. Labyrinth seals
2. Shims
3. Preformed packings
4. Piston lock nut

3-24. Shims provide adequate clearance between what two dome assembly parts?

1. The stationary cam and the blade segment gears
2. The sationary cam and the dome shell
3. The stationary cam and the piston
4. The rotating cam gear and the blade segment gears

3-25. The low pitch stop assembly is mounted to what other assembly?

1. Barrel assembly
2. Dome assembly
3. Propeller control assembly
4. Pump housing assembly

3-26. The component of the low pitch stop assembly which causes the piston wedge to move, allowing the piston stop levers to collapse inward is what unit?

1. The fluid transfer tube
2. The servo piston and shaft
3. The pressure regulating valve
4. The selector valve

3-27. The ratchet rings in the pitchlock regulator assembly are held apart by

1. hydraulic pressure
2. the servo assembly
3. air pressure
4. the cam assembly

3-28. When pitchlock occurs, what device prevents a decrease in the blade angle?

1. The flyweights
2. The stationary cam
3. The splined ring spacer
4. The ratchet rings

3-29. The component in the pitchlock assembly that prevents the propeller blade angle from decreasing when engine speed exceeds 103.5 percent is what unit?

1. The stationary pitchlock ring
2. The flyweight
3. The pitchlock control cam
4. The retaining ring

3-30. Pitchlock in the blade angle range of approximately 14.5 to 17 degrees is prevented by what condition?

1. Closed pitchlock servo valve
2. Reduced rpm
3. Pitchlock control cam action
4. Ratchet ring engagement

3-31. What are the two major parts of the 54H60-77 model propeller control assembly?

1. The synchrophasing system and the hydraulic reservoir
2. The pump housing assembly and valve housing assembly
3. The engine control system and negative torque system
4. The barrel assembly and the propeller blades

3-32. What is the hydraulic fluid (MIL-H-83282) capacity of the propeller system?

1. 10 quarts
2. 25 quarts
3. 10 gallons
4. 25 gallons

3-33. The valve housing assembly controls what two ranges of operation?

1. The beta and charley ranges
2. The alpha and delta ranges
3. The delta and alpha ranges
4. The alpha and beta ranges

3-34. What component in the valve housing assembly opposes the flyweight centrifugal force?

1. The pilot valve
2. The speeder spring
3. The speed reset bias plunger
4. The selector valve

3-35. What valve in the valve housing assembly directs pitch change hydraulic pressure to the dome assembly?

1. The pilot valve
2. The high pressure relief valve
3. The main regulating valve
4. The standby regulating valve

3-36. The propeller system is comprised of several assemblies, one of which is the pump housing. What is the location of the pump housing?

1. The lower part of the propeller control assembly
2. The upper part of the propeller control assembly
3. Inside the dome assembly
4. In the reduction gear assembly

3-37. What total number of pumps are located in the pump housing assembly?

1. Seven
2. Five
3. Three
4. Nine

IN ANSWERING QUESTION 3-38, REFER TO FIGURE 4-10 ON PAGE 4-15 OF THE TEXT.

3-38. What pumps in the pump housing assembly are driven by a common shaft?

1. The main pump and standby pump
2. The auxiliary main pump and auxiliary scavenge pump
3. The main scavenge pump and auxiliary scavenge pump
4. The auxiliary pump and main pump

3-39. What pump is located in the pump housing assembly?

1. Positive displacement vane pump
2. Variable displacement pump
3. Constant displacement pump
4. Positive displacement gear pump

3-40. When the propeller is in the feather position, what component secures power to the auxiliary pumps?

1. The pressure cutout switch
2. The feather valve
3. The pilot valve
4. The feather cutout switch

3-41. The pressurized sump in the pump housing assembly is supplied with a constant pressure of 18 to 22 psi from what pump?

1. The auxiliary main pump
2. The standby pump
3. The main pump
4. The main scavenge pump

3-42. The auxiliary main pump is commonly referred to as what pump?

1. The static ground pump
2. The scavenge pump
3. The feather pump
4. The standby auxiliary pump

3-43. During static ground operations, what pumps are used to feather and unfeather the propeller?

1. The auxiliary scavenge pump and feather pump
2. The main pump and feather pump
3. The standby pump and feather pump
4. The main scavenge pump and feather pump

Learning Objective: Recognize some of the major component buildup procedures for a propeller system.

3-44. During propeller assembly you should install which of the following components on the oil test post?

1. The front cone
2. The rear barrel half
3. The rear cone
4. The front barrel half

3-45. After the blade preformed packing is installed on the propeller blade butt, you can ensure the packing has been installed properly by checking what condition?

1. The embossed word "Bottom" on the packing is located in the rear barrel half
2. The embossed word "Bottom" on the packing is located in the front barrel half
3. The embossed word "Top" on the packing is located in the rear barrel half
4. The embossed word "Top" on the packing is located in the front barrel half

3-46. When assembling the propeller, a 30 minute waiting period is required after installing the propeller blade preformed packings. What is the purpose of the waiting period?

1. To allow the adhesive to set
2. To allow the lubricant to penetrate the packing
3. To allow the packing to return to its original shape
4. To allow for proper hardening of the packing

3-47. When assembling the propeller, you should install the microadjusting rings on what component?

1. On each blade butt
2. In each barrel half
3. In the dome assembly
4. On the pitchlock assembly

3-48. What index mark on the propeller blade microadjusting ring must be aligned with the tractor mark on the blade housing?

1. "19"
2. "18"
3. "17"
4. "16"

3-49. When you are assembling the propeller, all blades except one require the installation of a spider shim plate. What blade does NOT require the spider shim plate?

1. Number 1 blade
2. Number 2 blade
3. Number 3 blade
4. Number 4 blade

3-50. When viewing the rear barrel half parting surface from the outboard end, the four blade bores are numbered in what manner?

1. Clockwise
2. Counterclockwise
3. In even numbers
4. In odd numbers

3-51. When installing propeller blades in the barrel assembly, you should install what blade last?

1. Number 1 blade
2. Number 2 blade
3. Number 3 blade
4. Number 4 blade

3-52. During propeller assembly, when installing the blade into the Number 1 position of the barrel assembly, you should take which of the following precautions?

1. Ensure the propeller cones are properly sealed
2. Ensure the beta gear segment is properly meshed with the beta feedback pinion gear
3. Ensure beta gear segments are installed in the Number 1 and Number 4 positions
4. Ensure the special relieved bolt is in the Number 1 barrel borehole position

3-53. You must not turn the Number 1 blade beyond a +95 degrees or -15 degrees after installation, as the beta segment gear will disengage from the beta feedback shaft pinion gear.

1. True
2. False

3-54. Barrel bolt stud extensions are tightened to what elongation?

1. 0.032 to 0.039 inch
2. 0.024 to 0.031 inch
3. 0.016 to 0.023 inch
4. 0.008 to 0.015 inch

3-55. The dome assembly serial number must be identical to the serial number on what assembly?

1. The rear barrel half
2. The rotating cam
3. The thrust bearing retainer
4. The pitchlock control

3-56. The rotating cam must be in what position prior to installation?

1. The flight idle position
2. The take off position
3. The reverse position
4. The feather position

Assignment 4

Textbook Assignment: "Propeller Maintenance; Jet Engine Testing and Operation." Pages 4-19 through 5-12

Learning Objective: Identify the requirements for balancing a propeller and describe the different balancing methods.

4-1. A propeller blade backlash and blade resistance check is not required before performing the propeller balancing checks.

1. True
2. False

4-2. What must be done to the propeller dome assembly to avoid an erroneous final balance check?

1. Ensure the rotating cam is set at 87 degrees
2. Drain any residual hydraulic fluid from the dome
3. Install the pitchlock regulator assembly
4. Remove the dome retaining nut special head screw

4-3. When the propeller is being balanced, the blade pitch must be set to what degree?

1. 25°
2. 35°
3. 45°
4. 55°

4-4. Which of the following procedures is correct regarding the final balance of the propeller assembly?

1. Bolts, nuts, and washers are installed in the deicer contact ring holder assembly
2. Previously installed nuts, bolts, and washers in the deicer contact ring holder that are red in color can be replaced with heavier hardware
3. All previously installed hardware must be removed from the deicer contact ring assembly prior to final balance check
4. All of the above

4-5. What is the purpose of the red nuts, bolts and washers installed in the deicer contact ring holder assembly?

1. To obtain propeller final balance
2. To obtain propeller preliminary balance
3. To obtain deicer contact ring holder balance
4. To obtain a magnet assembly synchrophaser balance

4-6. The maximum number of AN960-10 washers used for final balancing must NOT exceed what total number?

1. One
2. Six
3. Three
4. Four

4-7. During preliminary balancing, you should install balance washers on what propeller component?

1. On the deicer contact ring
2. On the blade balance plug
3. On the barrel assembly
4. On the balancing arbor

Learning Objective: Identify the different types of hydraulic leakage tests.

4-8. During the external and internal leakage tests, what will cause erratic operation of the propeller blade movement?

1. Pressure of test equipment set too low
2. Pressure of test equipment set too high
3. A pitchlocked propeller
4. Air in the propeller system

4-9. During the external leakage test, a total of how many cycles must be completed with no evidence of leakage?

1. Six
2. Two
3. Eight
4. Four

4-10. A hydraulic leak occurs at the junction of the barrel half seals during the external leakage test. What action should you take to eliminate the leak?

1. Rotate the blade preformed packing
2. Replace the "worm" seal
3. Retorque the barrel bolts
4. Add zinc chromate putty

Learning Objective: Recognize the rigging and adjustment procedures for a propeller system.

4-11. What minimum number of rigging pins are required to rig and adjust a propeller system?

1. Five
2. Six
3. Seven
4. Eight

4-12. Which of the following conditions must be continuously maintained during the propeller control rigging procedure?

1. The blade caps are to remain in place
2. The sling hoist tension is maintained on the horizontal blades
3. The propeller control assembly is at least half way from the stop position
4. The propeller control assembly retainer lug remains against the reduction gearbox stop assembly

4-13. With the power lever at flight idle, the coordinator pointer must align with what degree mark on the protractor?

1. 0 degree
2. 34 degree
3. 86 degree
4. 90 degree

4-14. In rigging the valve housing assembly, you have adjusted the linkage rods and input lever. Next you should remove the rigging pins and move the power lever to what position?

1. Reverse
2. Feather
3. Ground idle
4. Takeoff

4-15. In troubleshooting the propeller system, you should understand which of the following normal operating details?

1. Airframe stress limits
2. Flight patterns for specified procedures
3. Ground handling procedures
4. Engine specifications

REFER TO TABLE 4-1 IN ANSWERING QUESTIONS 4-16 THROUGH 4-18. SELECT FROM COLUMN B THE CORRECTIVE ACTION TAKEN FOR EACH PROPELLER MALFUNCTION LISTED IN COLUMN A. SOME RESPONSES ARE NOT USED.

	A. MALFUNCTION	B. CORRECTIVE ACTION
4-16.	Propeller blades will not change pitch statically	1. Replace reduction gear box
4-17.	Propeller feathering action stops at blade angle of 72 to 76 degrees vice 86.5 degrees.	2. Replace propeller
		3. Replace defective components
4-18.	Pitchlock does not operate	4. Replace propeller control

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4-19. Without a rear cone, propeller fluid will be lost through leakage from the rear of the barrel tailshaft extension.

1. True
2. False

Learning Objective: Identify test cell functions and equipment, and the requirements for test cell operators

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4-20. Test cell operators can be certified by which of the following methods?

1. Formal training from a NARF school
2. On site training from a NAESU engineer
3. OJT by a certified senior petty officer
4. All of the above

4-21. All test cell operators must hold a valid support equipment license that contains which of the following information?

1. A particular engine and engine test cell
2. A particular type of engine and aircraft
3. A particular type of engine test cell and type of aircraft
4. A particular location/command

4-22. Engine test cells are equipped to measure which of the following parameters?

1. Engine weight only
2. Engine weight and length
3. All desired engine operating parameters
4. All desired aircraft operating parameters

4-23. The enclosed test facility is capable of handling how many pounds of thrust during the engine performance tests?

1. 17,000 lbs
2. 30,000 lbs
3. 35,000 lbs
4. 45,000 lbs

4-24. The enclosed test facility includes test equipment made up of a total of how many major assemblies?

1. Five
2. Six
3. Eight
4. Nine

4-25. Why is the variable height stand used when testing an engine?

1. To support the engine
2. To restrain the engine
3. To position the engine
4. All of the above

4-26. The thrust bed load beam actuates the thrust measuring system because of what variable height stand components?

1. The link rod couplings
2. The flexure plates
3. The hydraulic cylinders
4. The mounting rails

4-27. Prevention of excessive movement of the thrust bed during engine installation or removal is the function of what components?

1. The hydraulic cylinders
2. The flexure plates
3. The limit stops
4. The mounting rails

4-28. What type of controls are used to raise and lower the thrust bed?

1. Electrical controls
2. Mechanical controls
3. Hydraulic controls
4. Hydroelectric controls

Learning Objective: Identify the test facility power sources, functions, and locations and determine the purpose of the interlock system control points.

4-29. The exhaust augmenter assembly and the exhaust gas cooling system assembly are monitored by what type of control?

1. Automatic only
2. Manual only
3. Automatic and manual
4. Semi-automatic and automatic

4-30. During engine operation, the afterburner is automatically shut off if the exhaust stack temperature exceeds the preset temperature. What component performs this function?

1. The latching relay
2. The solenoid switch valve
3. The gate valve
4. The manually operated relay

4-31. Which of the following electrical power sources is NOT available to the test facility?

1. 115-volt ac, 1-phase, 60 Hz
2. 115-volt ac, 1-phase, 400 Hz
3. 28-volt dc
4. 120/208-volt ac, 3-phase, 60 Hz

4-32. In addition to supplying lifting force for height positioning of the thrust bed, oil pressure is used for which of the following purposes?

1. To drive the calibration cell cylinder
2. To drive the lateral positioning of the thrust bed
3. To restrict lateral movement of the thrust measurement system
4. To restrict the bed movement to a maximum height of ten feet

4-33. What is the rating of the power source used by the interlock system?

1. 115-volt ac, 1-phase
2. 120/208-volt ac, 3 phase
3. 110/145-volt dc
4. 28-volt dc

IN ANSWERING QUESTIONS 4-34 THROUGH 4-36, SELECT FROM COLUMN B THE SWITCHES AND PILOT LIGHTS LOCATED AT EACH INTERLOCK SYSTEM CONTROL POINT LISTED IN COLUMN A. SOME RESPONSES ARE NOT USED.

	A. CONTROL POINTS	B. SWITCHES/ LIGHTS
4-34.	No. 1	1. Front door bypass switch/ red pilot light
4-35.	No. 2	2. CO_2 pressure switch/greem pilot light
4-36.	No. 3	3. Front door key operated switch/green and red pilot lights
		4. Front door bypass switch/ white pilot light

4-37. The CO_2 system pressure switch contacts are broken. What must be done to complete the interlock system circuit?

1. Replace the pressure switch
2. Manually reset the pressure switch
3. Electrically reset the interlock system
4. Replace the CO_2 container

Learning Objective: Identify the stages of the exhaust augmenter system, and their functions.

4-38. The first stage exhaust augmenter is assisted in discharging exhaust gases to the second stage augmenter by what means?

1. Increased exhaust pressure
2. Outside airflow around the augmenter
3. Venturi action
4. Increased turbine pressure

4-39. Which of the following conditions results from improper sizing and positioning of the first stage augmenter?

1. Damage to the second stage augmenter
2. Bending of the augmenter diffusing vanes
3. Increase in exhaust gas temperature and thrust
4. Excessive exhaust back pressure and loss of thrust

4-40. Which of the following substances provides additional exhaust gas cooling in the second stage exhaust augmenter?

1. Carbon dioxide
2. Hydrogen chloride
3. Water
4. Air

Learning Objective: Identify the components in the test facility fuel, oil, and CO_2 systems and recognize all systems connected to the interlock system.

4-41. What is the total number, capacity and location of the test cell fuel tank(s)?

1. One 10,000-gallon fuel tank above ground
2. Two 10,000-gallon fuel tanks above ground
3. Two 10,000-gallon fuel tanks underground
4. One 10,000-gallon fuel tank underground

4-42. The fuel system is interlocked to what test equipment system(s)?

1. The basic interlock system only
2. The exhaust gas cooling system only
3. The CO_2 and exhaust gas cooling systems only
4. The basic interlock, CO_2, and exhaust gas cooling systems

4-43. What is the capacity of the engine oil reservoir?

1. 10 gallons
2. 20 gallons
3. 30 gallons
4. 40 gallons

4-44. The engine on which you are working requires use of the auxiliary lubricating system. By what means is the oil cooled in the heat exchanger before it is returned to the engine?

1. By water circulation through the exchanger
2. By water circulation around exchanger
3. By forced air over the exchanger
4. By forced air under the exchanger

4-45. To maintain engine oil outlet temperature limits, the oil temperature regulator is adjusted by activating which of the following valves?

1. Solenoid valve
2. Slide valve
3. Check valve
4. Handwheel valve

4-46. The CO_2 storage tank for the test facility holds what quantity of CO_2?

1. 1 ton
2. 2 tons
3. 3 tons
4. 4 tons

4-47. CO_2 must be refrigerated to maintain what property?

1. Its color
2. Its temperature
3. Its pressure
4. Its volume

4-48. For complete fire coverage of the test facility, the CO_2 is pressure linked to the main fuel line valve of the engine fuel supply and electrically linked to what system?

1. The intercommunication system
2. The control board system
3. The compressed air system
4. The interlock system

Learning Objective: Identify the different types of portable universal engine runup test systems and their functions.

4-49. The portable engine test cells may be used at any site location, providing which of the following types of tiedowns are used?

1. Concrete embedded
2. Flexible plastic
3. Nylon cord
4. Steel chains

4-50. What is the main purpose of the engine test log sheet?

1. To record engine data during the test run
2. To record work performed prior to the test run
3. To record the number of separate engines subjected to the test run
4. To record the position of the engine on the aircraft

4-51. Which of the following information is NOT a required entry on the engine test run log sheet?

1. Name of testing activity
2. Engine model
3. Engine serial number
4. Engine manufacturer

4-52. Which of the following information listed on the engine test log sheet has no absolute value?

1. The turbine inlet temperature
2. The acceleration time
3. The coast down time
4. The ambient air temperature

4-53. What person is responsible for entering the test data completely and accurately on the engine test run log sheet?

1. The work center supervisor
2. The maintenance personnel
3. The test cell operator
4. The division officer

4-54. What factor is used to establish the thrust indication on present day engines?

1. The engine pressure ratio
2. The compressor rpm
3. The exhaust gas pressure
4. The turbine rpm

4-55. Compressor rpm for a given engine thrust will be lower on a hot day than it is on a cold day.

1. True
2. False

4-56. Engine pressure ratio (EPR) will vary directly with which of the following variables?

1. The fuel flow
2. The engine speed
3. The engine thrust
4. The altitude of the test cell

4-57. Which of the following variables is monitored to ensure that temperature limits are not exceeded during a test run, but is NEVER used for setting thrust?

1. The engine pressure ratio
2. The engine rpm
3. The ambient temperature
4. The exhaust gas temperature

4-58. On a cold day, using EPR as the thrust indicator, the desired thrust rating of an engine may be reached at what percent rpm?

1. 100%
2. 101% to 110%
3. Something greater than 110%
4. Something less than 100%

4-59. The process of trimming is occasionally used to compensate for which of the following factors?

1. Thrust deterioration
2. Fuel flow
3. Exhaust gas temperature
4. Propeller speed

4-60. The nozzle size on some engines may be varied by the insertion of what devices?

1. Shims
2. Vanes
3. Stators
4. Mice

4-61. Although the variation of the exhaust nozzle is used in trimming some engines, what adjustment is made to bring the engine to a specific temperature?

1. The fuel control adjustment
2. The inlet guide vane adjustment
3. The speed sensing adjustment
4. The bleed valve adjustment

4-62. The rated thrust of an engine cannot be restored without exceeding the other limitations. What action should you take?

1. Disregard all other engine parameters and leave the engine in service
2. Field clean the engine
3. Request the factory representative to troubleshoot the engine
4. Remove the engine from service and tag it "condemed"

4-63. Which of the following compounds is used as a cleaning material for the field cleaning of an engine?

1. Peanut hulls
2. Walnut hulls
3. Wood chips
4. Metal chips

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8	☐	☐	☐	☐	_____	33	☐	☐	☐	☐	_____	58	☐	☐	☐	☐	_____
9	☐	☐	☐	☐	_____	34	☐	☐	☐	☐	_____	59	☐	☐	☐	☐	_____
10	☐	☐	☐	☐	_____	35	☐	☐	☐	☐	_____	60	☐	☐	☐	☐	_____
11	☐	☐	☐	☐	_____	36	☐	☐	☐	☐	_____	61	☐	☐	☐	☐	_____
12	☐	☐	☐	☐	_____	37	☐	☐	☐	☐	_____	62	☐	☐	☐	☐	_____
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14	☐	☐	☐	☐	_____	39	☐	☐	☐	☐	_____	64	☐	☐	☐	☐	_____
15	☐	☐	☐	☐	_____	40	☐	☐	☐	☐	_____	65	☐	☐	☐	☐	_____
16	☐	☐	☐	☐	_____	41	☐	☐	☐	☐	_____	66	☐	☐	☐	☐	_____
17	☐	☐	☐	☐	_____	42	☐	☐	☐	☐	_____	67	☐	☐	☐	☐	_____
18	☐	☐	☐	☐	_____	43	☐	☐	☐	☐	_____	68	☐	☐	☐	☐	_____
19	☐	☐	☐	☐	_____	44	☐	☐	☐	☐	_____	69	☐	☐	☐	☐	_____
20	☐	☐	☐	☐	_____	45	☐	☐	☐	☐	_____	70	☐	☐	☐	☐	_____
21	☐	☐	☐	☐	_____	46	☐	☐	☐	☐	_____	71	☐	☐	☐	☐	_____
22	☐	☐	☐	☐	_____	47	☐	☐	☐	☐	_____	72	☐	☐	☐	☐	_____
23	☐	☐	☐	☐	_____	48	☐	☐	☐	☐	_____	73	☐	☐	☐	☐	_____
24	☐	☐	☐	☐	_____	49	☐	☐	☐	☐	_____	74	☐	☐	☐	☐	_____
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PRINT OR TYPE

NRCC AVIATION MACHINIST'S MATE 1 & C
NAVEDTRA 10324-A

NAME ______________________________ ADDRESS ______________________________
Last First Middle Street/Ship/Unit/Division, etc.

City or FPO State Zip

RANK/RATE ________ SOC. SEC. NO. ________________ DESIGNATOR ________ ASSIGNMENT NO. ________

☐ USN ☐ USNR ☐ ACTIVE ☐ INACTIVE OTHER (Specify) ________________ DATE MAILED ________

SCORE

	1 T	2 F	3	4			1 T	2 F	3	4			1 T	2 F	3	4	
1	☐	☐	☐	☐	_____	26	☐	☐	☐	☐	_____	51	☐	☐	☐	☐	_____
2	☐	☐	☐	☐	_____	27	☐	☐	☐	☐	_____	52	☐	☐	☐	☐	_____
3	☐	☐	☐	☐	_____	28	☐	☐	☐	☐	_____	53	☐	☐	☐	☐	_____
4	☐	☐	☐	☐	_____	29	☐	☐	☐	☐	_____	54	☐	☐	☐	☐	_____
5	☐	☐	☐	☐	_____	30	☐	☐	☐	☐	_____	55	☐	☐	☐	☐	_____
6	☐	☐	☐	☐	_____	31	☐	☐	☐	☐	_____	56	☐	☐	☐	☐	_____
7	☐	☐	☐	☐	_____	32	☐	☐	☐	☐	_____	57	☐	☐	☐	☐	_____
8	☐	☐	☐	☐	_____	33	☐	☐	☐	☐	_____	58	☐	☐	☐	☐	_____
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17	☐	☐	☐	☐	_____	42	☐	☐	☐	☐	_____	67	☐	☐	☐	☐	_____
18	☐	☐	☐	☐	_____	43	☐	☐	☐	☐	_____	68	☐	☐	☐	☐	_____
19	☐	☐	☐	☐	_____	44	☐	☐	☐	☐	_____	69	☐	☐	☐	☐	_____
20	☐	☐	☐	☐	_____	45	☐	☐	☐	☐	_____	70	☐	☐	☐	☐	_____
21	☐	☐	☐	☐	_____	46	☐	☐	☐	☐	_____	71	☐	☐	☐	☐	_____
22	☐	☐	☐	☐	_____	47	☐	☐	☐	☐	_____	72	☐	☐	☐	☐	_____
23	☐	☐	☐	☐	_____	48	☐	☐	☐	☐	_____	73	☐	☐	☐	☐	_____
24	☐	☐	☐	☐	_____	49	☐	☐	☐	☐	_____	74	☐	☐	☐	☐	_____
25	☐	☐	☐	☐	_____	50	☐	☐	☐	☐	_____	75	☐	☐	☐	☐	_____

PRINT OR TYPE

NRCC AVIATION MACHINIST'S MATE 1 & C
NAVEDTRA 10324-A

NAME ______________________ ADDRESS ______________________
Last First Middle Street/Ship/Unit/Division, etc.

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RANK/RATE ______ SOC. SEC. NO. ______________ DESIGNATOR ______ ASSIGNMENT NO. ______

☐ USN ☐ USNR ☐ ACTIVE ☐ INACTIVE OTHER (Specify) ______________ DATE MAILED ______

SCORE

	1 T	2 F	3	4			1 T	2 F	3	4			1 T	2 F	3	4	
1	☐	☐	☐	☐	_____	26	☐	☐	☐	☐	_____	51	☐	☐	☐	☐	_____
2	☐	☐	☐	☐	_____	27	☐	☐	☐	☐	_____	52	☐	☐	☐	☐	_____
3	☐	☐	☐	☐	_____	28	☐	☐	☐	☐	_____	53	☐	☐	☐	☐	_____
4	☐	☐	☐	☐	_____	29	☐	☐	☐	☐	_____	54	☐	☐	☐	☐	_____
5	☐	☐	☐	☐	_____	30	☐	☐	☐	☐	_____	55	☐	☐	☐	☐	_____
6	☐	☐	☐	☐	_____	31	☐	☐	☐	☐	_____	56	☐	☐	☐	☐	_____
7	☐	☐	☐	☐	_____	32	☐	☐	☐	☐	_____	57	☐	☐	☐	☐	_____
8	☐	☐	☐	☐	_____	33	☐	☐	☐	☐	_____	58	☐	☐	☐	☐	_____
9	☐	☐	☐	☐	_____	34	☐	☐	☐	☐	_____	59	☐	☐	☐	☐	_____
10	☐	☐	☐	☐	_____	35	☐	☐	☐	☐	_____	60	☐	☐	☐	☐	_____
11	☐	☐	☐	☐	_____	36	☐	☐	☐	☐	_____	61	☐	☐	☐	☐	_____
12	☐	☐	☐	☐	_____	37	☐	☐	☐	☐	_____	62	☐	☐	☐	☐	_____
13	☐	☐	☐	☐	_____	38	☐	☐	☐	☐	_____	63	☐	☐	☐	☐	_____
14	☐	☐	☐	☐	_____	39	☐	☐	☐	☐	_____	64	☐	☐	☐	☐	_____
15	☐	☐	☐	☐	_____	40	☐	☐	☐	☐	_____	65	☐	☐	☐	☐	_____
16	☐	☐	☐	☐	_____	41	☐	☐	☐	☐	_____	66	☐	☐	☐	☐	_____
17	☐	☐	☐	☐	_____	42	☐	☐	☐	☐	_____	67	☐	☐	☐	☐	_____
18	☐	☐	☐	☐	_____	43	☐	☐	☐	☐	_____	68	☐	☐	☐	☐	_____
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22	☐	☐	☐	☐	_____	47	☐	☐	☐	☐	_____	72	☐	☐	☐	☐	_____
23	☐	☐	☐	☐	_____	48	☐	☐	☐	☐	_____	73	☐	☐	☐	☐	_____
24	☐	☐	☐	☐	_____	49	☐	☐	☐	☐	_____	74	☐	☐	☐	☐	_____
25	☐	☐	☐	☐	_____	50	☐	☐	☐	☐	_____	75	☐	☐	☐	☐	_____

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